THE JOURNAL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

DECEMBER 1959

Vol. 53, No. 6 Whole No. 441

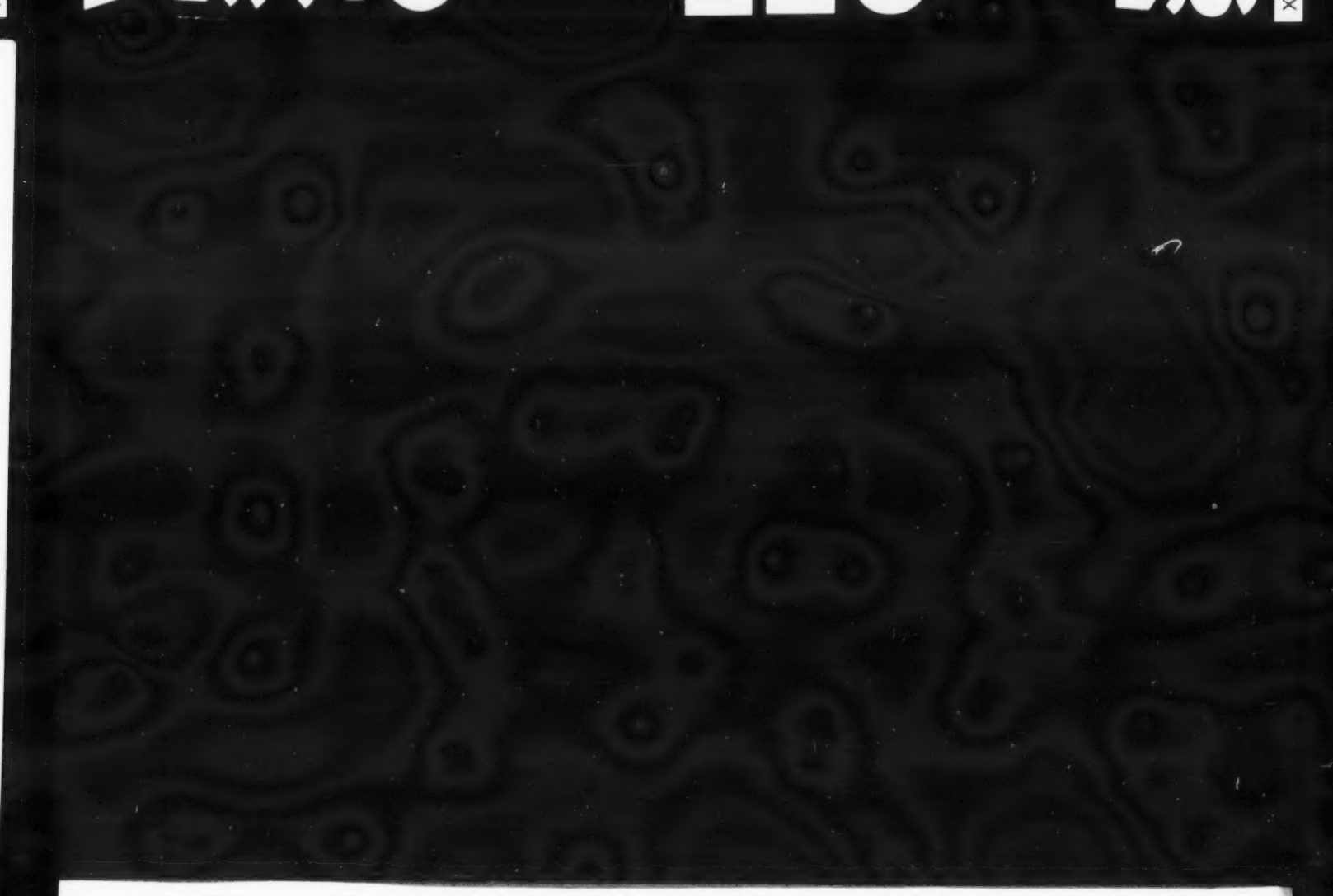
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

NATIONAL OFFICERS AND COUNCIL FOR 1959

Honorary President—The Honourable W. J. DUNLOP, D.PAED., Minister of Education for Ontario.
President—ANDREW MCKELLAR, PH.D., Victoria.
First Vice-President—PETER M. MILLMAN, PH.D., Ottawa.
Second Vice-President—RUTH J. NORTHCOTT, M.A., Toronto.
National Secretary—J. E. KENNEDY, M.SC., 252 College Street, Toronto 2B.
National Treasurer—J. H. HORNING, M.A., 252 College Street, Toronto 2B.
Recorder—FREDERIC L. TROYER, Toronto.
Librarian—W. T. TUTTE, PH.D., Toronto.
Council—Elective Members: MIRIAM S. BURLAND, Ottawa; A. VIBERT DOUGLAS, Kingston; CARL REINHARDT, Toronto; Past Presidents—HELEN S. HOGG, Toronto; R. M. PETRIE, Victoria.

Calgary Centre: E. J. MCCULLOUGH, WALTER H. STILWELL (Pres.).
Edmonton Centre: E. S. KEEPING, EARL MILTON (Pres.).
Halifax Centre: Rev. M. W. BURKE-GAFFNEY, S.J., MURRAY E. HIGGINS (Pres.).
Hamilton Centre: GRANT M. VANSICKLE, J. G. CRAIG (Pres.).
London Centre: W. GORDON GRAHAM, W. WEHLAU (Pres.).
Montreal Centre: C. M. GOOD, A. R. MACLENNAN (Pres.).
Centre Français de Montréal: ROMEO GRIGNON, PIERRE LEMIEUX (Pres.).
Ottawa Centre: J. L. LOCKE, J. E. LILLY (Pres.).
Quebec Centre: MAURICE DROLET, J. ALFRED DUMONT (Pres.).
Toronto Centre: J. F. HEARD, LEONARD SEARLE (Pres.).
Vancouver Centre: J. A. JACOBS, V. J. OKULITCH (Pres.).
Victoria Centre: NORMAN G. ROGERS, J. A. L. MUIR (Pres.).
Windsor Centre: C. K. CARRINGTON, LAMBERT HUNEAULT (Pres.).
Winnipeg Centre: R. J. LOCKHART, J. SCATLIFF (Pres.).

PRINTED IN CANADA
BY THE UNIVERSITY OF TORONTO PRESS



THE JOURNAL OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

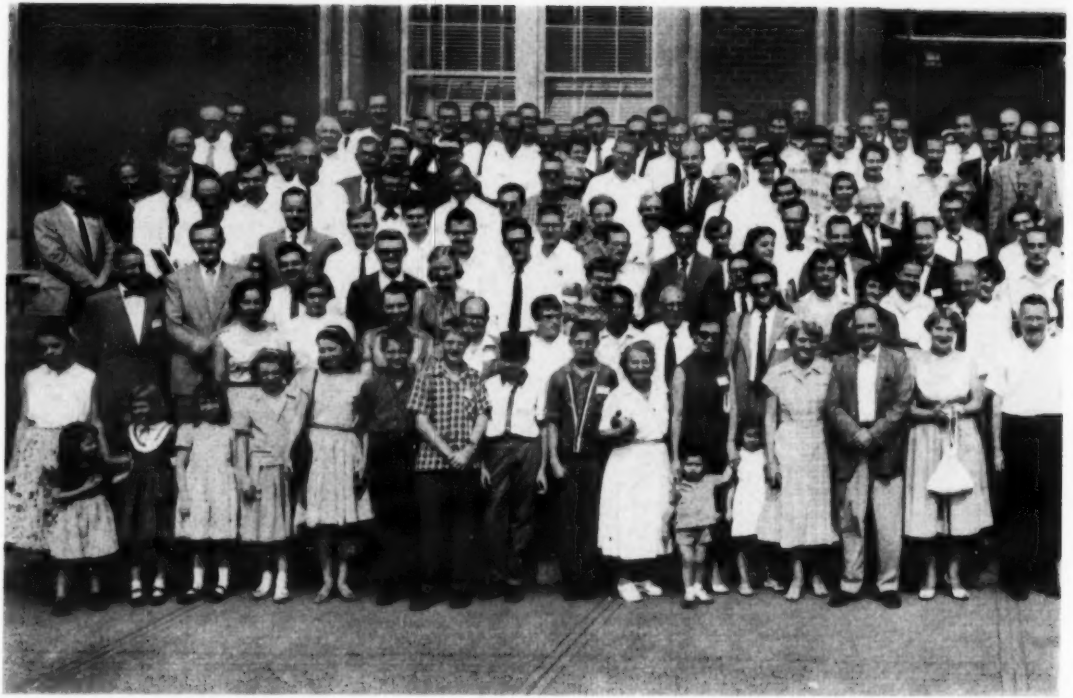
Vol. 53, No. 6 DECEMBER 1959 Whole No. 441

TORONTO MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY

At the invitation of Dr. John F. Heard, Director of the David Dunlap Observatory, the 103rd Meeting of the American Astronomical Society was held at the University of Toronto, August 30th–September 2nd, 1959. The meeting was the biggest in the Society's history being attended by approximately two hundred astronomers together with their families and guests. More than seventy papers were read to the Society reporting the results of recent research; one-fifth of these were by Canadian astronomers. The Dominion Observatory, Ottawa; The Dominion Astrophysical Observatory, Victoria; The National Research Council, Ottawa; Atomic Energy of Canada, Chalk River; Queen's University, Kingston; and the David Dunlap Observatory, University of Toronto, were all represented at the meetings.

The Society's annual Russell Lecture was given by Gerard P. Kuiper, Director of the Yerkes Observatory. Speaking on the subject of "Planets and Satellites", Kuiper outlined highlights of recent researches and viewpoints about the solar system. He gave special emphasis to the moon, showing many magnificent photographs which will form part of the new lunar atlas to be published at Chicago this autumn, and he gave his explicit reasons for rejecting the "dust bowl" theory of the lunar seas in favour of his conviction that the maria are lava flows. Speaking of Mars he demonstrated to his audience that the so-called greenish areas are in fact not green but gray; and he was emphatic in his denial of the existence of a network of canals as sketched by many observers, explaining that this illusion arises from imperfectly resolved fine detail of great complexity.

Another feature of the Toronto meeting was a symposium on the sub-



Meeting of the American Astronomical Society at the University of Toronto, September 1959.

Meeting of the American Astronomical Society at the University of Toronto, September 1959.

ject "The Differences Among Globular Clusters". The symposium was moderated by Sandage (Mount Wilson and Palomar Observatories) and opened by Helen Hogg, (David Dunlap Observatory) who pointed out that it had been customary to overlook these differences but emphasized that there was an impressive amount of evidence suggesting that the globular clusters can no longer be considered as an homogeneous group of essentially identical objects. Arp (Mount Wilson and Palomar Observatories) emphasized the differences among the Hertzsprung-Russell diagrams of the globular clusters and discussed at length the vexing problem of the absolute magnitude zero point for these diagrams.

Sandage read a paper by Thackeray (Radcliffe Observatory, South Africa), reporting on recent studies of the globular clusters in the Magellanic Clouds. The red globulars in the Clouds appear to be very similar to those in the Galaxy, he reported, but there are also blue clusters, globular in appearance, which have no galactic counterparts.

Morgan (Yerkes Observatory) discussed his studies of the integrated spectra of globular clusters emphasizing that metal-rich globulars tend to lie in the galactic plane while the metal-poor clusters have a more nearly spherical distribution about the galactic centre. Mayall (Lick Observatory) read the last paper of the symposium, written jointly by himself and Kron (Lick Observatory), discussing their observations of the integrated colours of the globular clusters.

Those who attended the scientific sessions were very appreciative of the refreshments which were provided during the intermissions by the Royal Astronomical Society of Canada. Many members of the Toronto and neighbouring centres attended the Russell Lecture.

POLARIS AND PRECESSION

By Charles H. Smiley and Abdul Majid Khan
Brown University, Providence, Rhode Island

A question often asked is the following: "When will the north celestial pole of rotation of the earth next be nearest Polaris, and how far will it then be from the pole?" To limit the question to a matter of precession, one may rephrase it thus: "What is the next year in which the declination of the mean position of Polaris for the year will be greater than that for the preceding year and that for the following year, and what will be the difference between that maximum declination and 90°?"

The usual text-book treatment suggests that precession appears to rotate the entire sky about a line joining the north and south poles of the ecliptic. In reality, there is a small and continuing annual decrease in the obliquity of the ecliptic, amounting to about 0.4685″. Thus the effect of precession over any particular interval of years can be considered as a rotation about a specific line which will differ slightly from the line of poles of the ecliptic. Also if one considers a series of intervals, say 1900–2000, 2000–2100, 2100–2200, one finds the effective axis of rotation is slightly different for each of these periods.

The precession formulae commonly given in standard references were designed for limited intervals of time to take care of stars which are not too near the poles. To determine how the declination of Polaris will change over a period of several centuries, one may use formulae made available by Thadee Banachiewicz (1924) and L. J. Comrie (1933). They are:

$$\begin{aligned} x &= A_{11}x_o + A_{12}y_o + A_{13}z_o \\ y &= A_{21}x_o + A_{22}y_o + A_{23}z_o \\ z &= A_{31}x_o + A_{32}y_o + A_{33}z_o \end{aligned} \qquad (1)$$

They may be used to transform equatorial rectangular co-ordinates (or direction cosines) from one mean equinox to another.

A few comments about these equations may be worth while. For example, the points (1,0,0), (0,1,0) and (0,0,1) will be transformed into the points whose co-ordinates are (A_{11}, A_{21}, A_{31}), (A_{12}, A_{22}, A_{32}) and (A_{13}, A_{23}, A_{33}) respectively. Each of these three points must be at unit distance from the origin since the original three points were. Thus:

$$\begin{aligned} A_{11}^2 + A_{21}^2 + A_{31}^2 &= 1 \\ A_{12}^2 + A_{22}^2 + A_{32}^2 &= 1 \\ A_{13}^2 + A_{23}^2 + A_{33}^2 &= 1 \end{aligned} \qquad (2)$$

The co-ordinates of the three transformed points above may be described therefore as the direction cosines of the three lines into which the x-axis, the y-axis and the z-axis of the original co-ordinate system are transformed. Since the three co-ordinate axes were mutually perpendicular, the three transforms will also be mutually perpendicular. Hence:

$$\begin{aligned} A_{11}A_{12} + A_{21}A_{22} + A_{31}A_{32} &= 0 \\ A_{12}A_{13} + A_{22}A_{23} + A_{32}A_{33} &= 0 \\ A_{13}A_{11} + A_{23}A_{21} + A_{33}A_{31} &= 0 \end{aligned} \tag{3}$$

One disadvantage of the precession formulae (1) is that the coefficients are not always easily available. Comrie (1933) gave the values to eight decimals of the coefficients needed to transform equatorial rectangular co-ordinates from 1950.0 to other equinoxes; he also gave expressions for these coefficients in terms of T, the number of centuries from 1950 to the year of the equinox to which the co-ordinates are to be transformed:

$$\begin{aligned} A_{11} &= 1.0000\ 0000 - 0.0002\ 9696\ T^2 - 0.0000\ 0014\ T^3 \\ A_{12} &= -A_{21} = -0.0223\ 4941\ T - 0.0000\ 0676\ T^2 + 0.0000\ 0221\ T^3 \\ A_{13} &= -A_{31} = -0.0097\ 1691\ T + 0.0000\ 0206\ T^2 + 0.0000\ 0098\ T^3 \\ A_{22} &= 1.0000\ 0000 - 0.0002\ 4975\ T^2 - 0.0000\ 0015\ T^3 \\ A_{23} &= A_{32} = -0.0001\ 0858\ T^2 \\ A_{33} &= 1.0000\ 0000 - 0.0000\ 4721\ T^2 + 0.0000\ 0002\ T^3 \end{aligned} \tag{4}$$

Banachiewicz included in each year's edition of *Rocznik Astronomiczny* the values to eight decimals of the coefficients needed to transform the equatorial rectangular co-ordinates from that year to certain other years; since his death, this custom has been continued.

To find the closest approach of the north celestial pole to Polaris, one needs the right ascension and declination of Polaris for 1950.0. They are:

$$\alpha = 1^h 48^m 48.61^s; \quad \delta = +89^\circ 01' 43.72''$$

Using these values, one finds the direction cosines for Polaris for 1950.0 as follows:

$$\begin{aligned} \cos\delta \cos\alpha &= +0.0150\ 7493 \\ \cos\delta \sin\alpha &= +0.0077\ 4831 \\ \sin\delta \qquad &= +0.9998\ 5635 \end{aligned}$$

Using equations (4) above, the coefficients needed to transform co-ordinates (or direction cosines) from 1950.0 to 2000.0, 2100.0 and

2200.0 are found and used. The resulting values for the third direction cosine, sin δ and for $90° - \delta$ are:

Year	sin δ	$90° - \delta$
2000.0	0.9999 1756	0°44′08.5″
2100.0	0.9999 6792	0°27′32.0″
2200.0	0.9999 2216	0°42′54.0″

This would indicate that the pole will be nearest to Polaris shortly after 2100. Calculating and using the coefficients for the next three years, one finds:

Year	sin δ	$90° - \delta$
2101.0	0.9999 6794	0°27′31.67″
2102.0	0.9999 6795	0°27′31.50″
2103.0	0.9999 6795—	0°27′31.55″

This suggests that the north celestial pole will be nearest Polaris in 2102 and its minimum distance 0°27′31.50″ differs from the distances in 2101 and 2103 by only a few hundredths of a second of arc. It seems likely that before A.D. 2100, improved values of the precessional constants will be available and a more precise determination of the time and distance of the closest approach of the north celestial pole to Polaris may be made.

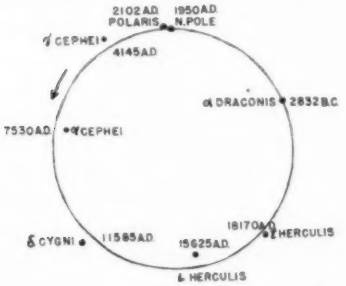


FIG. 1

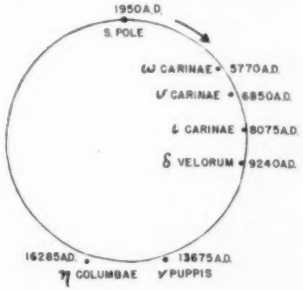


FIG. 2

In figures 1 and 2 are shown the paths of the two celestial poles, north and south, due to precession, and some of the stars which have been and will be useful as Pole Stars in the Northern and Southern Hemispheres.

REFERENCES

Banachiewicz, T. 1924 and successive years to 1959, *Rocznik Astronomiczny Obserwatorjum Krakowskiego*, Supplemento internationale.

Comrie, L. J. 1933, *Planetary Co-ordinates for the Years 1800–1940 Referred to the Equinox of 1950.0*. London; See also 1926, "The Use of a Standard Equinox in Astronomy", *Monthly Notices, R.A.S.*, vol. 86, p. 618.

HISTORICAL RESEARCH IN ASTRONOMY*

By J. E. Kennedy†
National Secretary, R.A.S.C.

Most people associate dates with historical events, a few dates like 1066, 1215 and 1492 remain in our memories—can you still recall the importance of these particular years? What will be remembered about this "wonderful year" 1959? It marks the one hundred and twentieth anniversary of observatory observations in Canada, started on this university campus within sight of where we are now assembled. It marks the centenary of the death of W. C. Bond, who had a close association with early astronomy in Canada, as observer and first Director of Harvard College Observatory. It marks "year three" of the Sputnik age, a year when a new planet has opened up an era in which astronomy has become a true experimental science.

Yes, in looking back, we will recall this "wonderful year", a time when people were saying:

"The ceaseless progress of science is to be seen everywhere. My daughter, aged three, has just been taught by her older brother to count 'five, four, three, two, one, zero'. She has not yet learned to count the other way round." (*The New Scientist*, vol. 4, July 10, 1958.)

"What are Sputniks to me? They are the modern equivalents of the Pyramids—a colossal technical achievement accomplished for the greater glory of political bosses and at the expense of the wretched fellaheen—us." (*The New Scientist*, vol. 4, July 17, 1958.)

"The Egyptians utilized 20 per cent. of their national potential for 20 years to build the Great Pyramid. If we applied the same percentage of national effort for the same time, we could put the pyramids into orbit. I want to go on record that I am not advocating it." (*Aviation Week*, vol. 68, May 5, 1958.)

This is the present—has the first quotation persuaded you to support our educators in their proposals for teaching more mathematics in our schools? Pyramids and Sputniks—does this association surprise you? The Pyramids are today only a tourist attraction having failed to fulfil their intended purpose. Are Sputniks headed for a similar fate?

In our daily routine, we are continuously exposed to and influenced by

*Substance of a paper read at the Annual Meeting, March 14, 1959.
†Defence Research Medical Laboratories.

such conflicting points of view; yet we are expected to carry on normal scientific pursuits! What better treatment could a psychiatrist suggest than developing a hobby or stimulating an interest in astronomy? Then if historical research in astronomy has an appeal, I would gladly welcome you as new associates adding stimulus to this field. What has been accomplished in historical research in astronomy in Canada?

If we regard history as the study of the past and research as the daily pursuit of many of us, then "historical research" may be defined as the scientific unravelling of the accumulation of the data provided by the past. The observational astronomer is concerned primarily with the study of events which have occurred in the past, years or centuries ago. Hence, one section of historical research in astronomy consists of looking back at our early astronomers who were in turn looking back on events—which were then history. There are other facets as well which will be apparent from the selection of material to follow.

Should we be content to leave the past and look only to the future? This is the dilemma that must be faced—the past may seem dull—the future may appear exciting. Here is an event from the past—the year 1858: "As the Comet approached the Sun towards the end of September, those possessed of good telescopes witnessed a series of extraordinary phenomena. A crescent-shaped outline, or luminous sector was seen to be interposed like a screen or shield between the nucleus and the Sun. This sector seemed to be in a state of perpetual commotion, as if agitated by the action of powerful internal forces; and the matter composing it was being continuously dissipated and carried off into the tail. The loss thus occasioned was supplied by sudden and violent disruptions from the central body, which was seen to project immense volumes of its luminous substance first towards the Sun. This projected matter was afterwards in conformity with some unknown law, repelled in the opposite direction, and driven off to the distant regions of space, thus forming the vast train of light so characteristic of the mysterious bodies. Numerous stars were observed through the densest parts of the tail, but their positions were not in the slightest degree changed by the effect of refraction, notwithstanding that the thickness of the medium through which they were seen was at least 2,000 times greater than that of our own atmosphere. This circumstance proves the extreme rarity—the almost infinitesimal tenuity—of this portion of the matter composing the Comet. You may also have noticed it remarked, without being aware of the inference deducible from the fact, that the light of the Comet exhibited traces of *polarization*. This indicates that it shines, at least partially by the reflected light of the sun; though circumstances are not wanting to give probability to the supposi-

tion that Comets are to a certain extent self-luminous." This, as you may have suspected, was a description of the appearance of Donati's Comet as given in a lecture by a Canadian Astronomer to a Canadian audience 100 years ago. This man, who may be considered as the father of Canadian astronomy was William Brydone Jack, a Scot by birth, a mathematician and astronomer by training, a University president—not entirely by choice, but above all else the person who launched observational astronomy and astronomical research in Canada.

The First Astronomical Observatory in Canada was built in Fredericton, New Brunswick, by William Brydone Jack and was recognized as such by the Historic Sites and Monuments Board in 1955 (this JOURNAL,

FIG. 1—The first astronomical observatory in Canada at Fredericton, New Brunswick.

vol. 49, pp. 151, 181, 1955). There are many things in which members of The Royal Astronomical Society of Canada should take pride and high on the list is the marking by our government of this historic building. Places where man's differences with man were settled by non-peaceful methods can be easily marked—a battlefield or a fort—but it has been more difficult for authorities to realize that advances have been made

by other means and deserve recognition. The wording of this plaque is a true indication of how differences were settled by peaceful methods.

First Astronomical Observatory in Canada

Built in 1851 at the instigation of William Brydone Jack, Professor of Mathematics, Natural Philosophy and Astronomy. President of the University of New Brunswick 1861–85. Schooled in the traditions of the Scottish Universities he equipped the Observatory with the best instruments of the day. In collaboration with Harvard Observatory he determined the longitude of Fredericton and other places in New Brunswick and corrected errors in the International Boundary.

In figure 1 the small frame building with the transit hatch is clearly shown. The dome is octagonal (eight-sided), a construction that is believed unique among observatories. The original telescope by Merz of Munich has been restored to a reasonable operating condition; one feature of this instrument is its fine mahogany tube.

The pier supporting the 6-inch equatorially-mounted refracting telescope seemed to have been added long after the original building was completed. The cement and external finish were out of keeping with the other parts of the building. At one stage of the renovation, the mounting bracket for the telescope was removed from the top of the pier and the evidence shown in figure 2 confirmed this assumption. It is of interest to note that the building plans of the Brydone Jack Observatory were dis-

FIG. 2—The top of the pier supporting the 6-inch refractor.

covered by Sir Harold Spencer Jones in the Archives of the Royal Greenwich Observatory at Herstmonceux. A study of these building plans has not entirely clarified the construction of the original pier.

The aim of a scientist is to bridge the gaps between the known and unknown, extending the frontiers of knowledge and crossing new frontiers. There are many gaps to be bridged in the field of historical research in astronomy. As an example, figure 3 shows an instrument known as a quadrant—this is the O'dell Quadrant, presented in 1846 to King's College, Fredericton, as recorded in this minute book. We are reasonably certain that no other quadrant is preserved in museums or archives in Canada. A few facts are known about its past; it was owned by William Franklin O'dell, Provincial Secretary of New Brunswick. We believe that he used it in the border survey between Maine and New Brunswick early in the nineteenth century. This is the information unearthed, the origin and

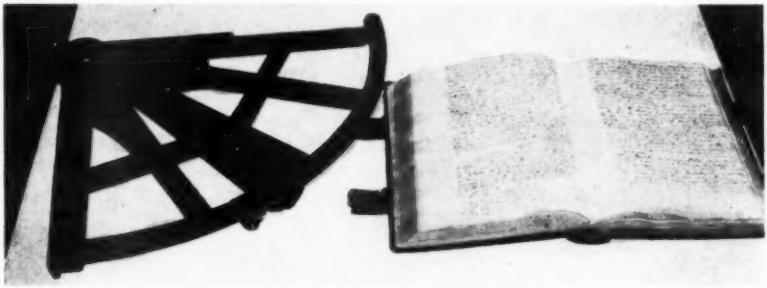


FIG. 3—*Left*: the O'dell Quadrant. *Right*: the minute book showing the record of the presentation in 1846 of the quadrant to King's College, Fredericton.

maker of the instrument are still in the realm of speculation. How can these missing links be acquired to complete this story? This is the challenge of historical research in astronomy.

These are selected examples from our past, unnoticed by many but each adding something to our heritage. William Brydone Jack looked to the future, examined events of the past and built a solid foundation on which astronomy in Canada has grown during the past century. Yes, the future is still exciting and full of promise, but the past is exciting and full of fact.

THE FIGURE OF THE EARTH

By R. K. C. Johns
Cambridge, Massachusetts

The shape and dimensions of the earth have been of interest to mankind from earliest times. The conception of what the earth looks like and its position in the universe has varied through the ages. The interest in the figure of the earth also has been motivated by practical considerations, for in order to travel and navigate from one place to another, the directions and the distances must be known.

The first approximate but scientific notion of the shape or figure of the earth was a sphere and was given by Aristotle and Eratosthenes. Twenty centuries later Newton calculated that centrifugal force causes the earth to bulge at the equator and thus showed the earth to be an oblate spheroid. Now we are learning more about the actual shape of the earth and are hopeful of obtaining more accurate information regarding the relative positions of continents. It has become apparent that man-made satellites provide an important tool in the hands of geodesists.

In ancient civilizations the earth was considered to be a flat disk surrounded by oceans and in one way or another placed in the centre of the celestial system. For example, early Chinese maps show the lands of the earth consisting of islands, swimming in water, surrounding one enormous country—the middle Kingdom of China.

The Greek philosopher Plato was the first to have had the courage to assert that the earth is not the centre of the universe but only one of many planets. After him Aristotle suggested the earth is a sphere. The Greeks were able to measure the obliquity of the earth's orbit. In the third century B.C., Eratosthenes, the librarian of Alexandria, completed the first determination of the earth's radius in human history. He chose two stations, one in Aswan and the other in Alexandria. At the summer solstice in Aswan the sun at noon time was exactly overhead shining straight in a deep well. At the same time in Alexandria, 500 miles north, the sun's rays and the zenith were enclosing an angle, z, a little over 7 degree of arc. (See figure 1.)

Assuming that the sun's rays are parallel, the angle measured at Alexandria corresponds to the angle between the plumb lines which is identical with the angle at the centre of the earth's sphere, as indicated in figure 1. Eratosthenes had exceptionally good luck. His results were nearly perfect, although everything he did seems to have been inaccurate.

His arc was measured incorrectly; so was his angle. Eratosthenes measured the distance between the two stations, calculating a radius for the earth of 3,488 nautical miles. A recent figure calculated by the U.S. Army Map Service is 3,444 nautical miles.

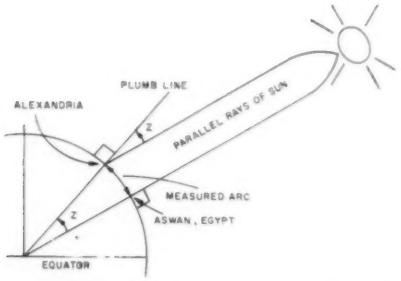


FIG. 1—How Eratosthenes measured the earth.

Through Arab scientists Greek geodetic knowledge reached Renaissance Italy from which scientific interest in the figure of the earth spread throughout Europe. Later Newton established his theorem showing the earth to be an oblate spheroid. Three determinations of the earth's figure completed under the auspices of the French Academy of Science at the end of the eighteenth century proved Newton's concept correct. The new era of geodesy, the science of the figure of the earth, began. Ideas and definitions were developed and international organizations of geodesists were formed where controversial items could be discussed, and ideas and information exchanged.

The geodetic question of the dimensions and shape of the earth has always been of basic scientific interest. However, it also has an increased significance for modern air traffic, for rocketry, and in other fields. Particularly for ballistic missiles, where high altitudes and long distances are involved, the exact knowledge of position as well as accuracy of vertical and horizontal directions have a decisive importance. More accurate knowledge of the earth's surface is becoming a necessity.

The surface of the earth consists of lands and seas, and it is customary to call the surface formed by mean sea level the geoid. The geoid is thus an approximation to the earth's shape and size; the real earth's surface is irregular with the Rocky Mountains above the level geoid, and Death Valley below. Although the geoid has a rather abstract definition, nevertheless it has physical reality. (See figure 2.)

The geoid is a surface that is difficult to represent mathematically and

therefore cannot conveniently be used as a reference surface for navigation, surveying and mapping. In its place a surface capable of mathematical representation is adopted, with a shape which closely approximates the geoid. Such a surface is a spheroid of reference whose geometrical centre coincides with the centre of gravity of the geoid and whose north-south axis is identical with the earth's axis of rotation.

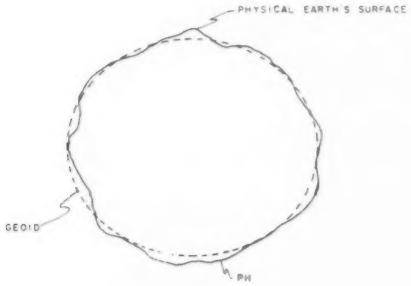


FIG. 2—The geoid.

In the twentieth century the basic Eratosthenesian idea of arc measurement is still followed in determining the figure of the earth. The direct measurement of a distance is replaced by a chain of triangles as represented in figure 3, or derived from a geodetic network of an area. Of course, astronomical observations are included. The arc is recalculated as though all points of the arc were transferred to the geoid at sea level. (See figure 3.)

Several different arc determinations produce various radii of the earth's curvature, and it is through the mathematical reconciliation of the arcs

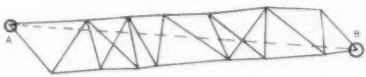


FIG. 3—Geodetic arc measurement between *A* and *B*.

with the corresponding radii of curvature that we have come to adopt as the reference figure the so-called spheroid of reference. It can be expected that the resulting spheroid will be the "best fit" only to the survey data used to determine it, and will always be an approximation valid only in the area of the surveys. But the spheroid of reference has great advantages over the geoid: maps can be shown on it; angles and distances can

be computed; and the deviations of the geoid from the spheroid can be determined with certain accuracy.

In Table I, the dimensions of some reference spheroids deduced from geodetic surveys, are given.

TABLE I

DIMENSIONS OF EARTH'S SPHEROIDS

Determination		Equatorial Semi Axis metres	Polar Flattening
Bessel	1841	6,377,397	1:299.15
Clarke	1866	6,378,206	1:294.98
Hayford	1909	6,378,388	1:297.0
Krassowski	1942	6,378,295	1:298.4
Hough	1956	6,378,270	1:297
Krassowski (U.S.S.R. reference spheroid)		6,378,245	1:298.3

In North American surveys, the reference figure used is that of Clarke, computed in 1866. This spheroid of 1866 differs somewhat from others, but in the area of North America it offers a fairly good approximation to the geoid.

As mentioned previously the spheroid of reference is only an approximation and there exist deviations of the geoid with respect to the spheroid which can be expressed in terms of the deflections of the geoid-vertical and in elevations of the geoid above the spheroid. The deflection of the vertical is the angle enclosed between the plumb bob hanging at the station and the perpendicular to the spheroid at this station. If astronomical data is compared with the geodetic data, these discrepancies can be expressed in terms of latitude and longitude, azimuth and distance. Fortunately there is a method for comparing the astronomical and geodetic data in order to control the precision of surveys. The deviation of the plumb line is caused by topography in the area surrounding the station and the variation of density in the earth's crust.

The difference between the apparent motion of stars and the period of the moon's revolution is the basis for lunar methods in geodesy. Information about the earth is provided by calculating the position of the moon among the reference stars of the celestial sphere. The study of the moon in eclipse occurring as the earth's shadow passes over it also supplies data for location evaluation on the earth. Both of these methods suffer, however, because of imprecise knowledge of the moon's profile and of the distance between the centres of gravity of the moon and the earth. The same can be said about the sun's eclipses. The lunar methods have many

practical advantages and have been largely applied in the past. Lately there has been a revival of interest in lunar methods. It has been proposed to use a lunar camera to photograph the moon against the stellar background. Then from known stars the position of the moon in terms of local co-ordinates of the station can be computed.

The arc measurement, position determination from star observation, and lunar methods may be considered as mainly geometric approaches to the determination of the figure of the earth. The physical approach to the determination of the shape of the earth is based primarily on the measurement of gravity variations on the surface of the earth.

The gravity value measured at a station, by means of a pendulum or another kind of a gravimeter, depends mainly on the geographic position of the station and on attraction of local and distant masses. The comparison of gravity data deduced from the assumption that the earth is a perfect spheroid, and the value of gravity at sea level, enables us to gather information about the actual shape of the earth. A great amount of gravity information has been collected already by geologists. In addition, ingenious devices for use on ships and in submarines make gravity observations possible on the sea, whereas other geodetic surveys and astronomical observations are limited of course to land areas. It is possible to detect plumb deviations from the gravity anomalies with a precision of a fraction of a second of arc.

Besides the question of the figure and shape of the earth, its gravity centre, etc., there exists the geodetic problem of determining the relative positions of continents. When we undertake a survey for map making purposes involving the stretching of long chains of triangles across the continent, we rely upon measurements of distances and of directions with extremely precise surveying instruments. But the measurements have been made only as far as the shoreline of the continents. There they stop.

As indicated before, a spheroid of reference is calculated to represent closely the size and shape of the earth in the survey area. Map makers of different countries have used surfaces of different shapes and dimensions.

The problem arises of how to connect one set of geodetic latitude and longitude data across the unmarked ocean to another set of geodetic values related to different spheroids of reference and having different Datum systems—a vital question for those concerned with aiming ballistic missiles.

What we need in this instance is a network of some kind to cross the oceans. This would require measurements of either distances or angles. A radar reflector or a slave transmitter placed on the moon's surface

TABLE II

Distance km.	Altitude km.
1000	20
2000	80
3000	181
4000	328
5000	525
6000	779
7000	1101

would provide a good apex for intercontinental ties enabling the geodesist to measure accurately the distance from various places on both coasts of the ocean to the moon.

The advent of the artificial satellite has already opened up new possibilities to the geodesist. He sees in it properties which are useful in triangulating a connection between two geodetic surveys. The satellite, due to its altitude above the ground, can be observed simultaneously from two widely separated points.

Table II gives the altitudes required for observations of the satellite seen at the same time in the horizon of two stations. The approximate data is based on the assumption that the earth's radius is 6,370 km.

In respect to the above table it may be noted that the shortest distance

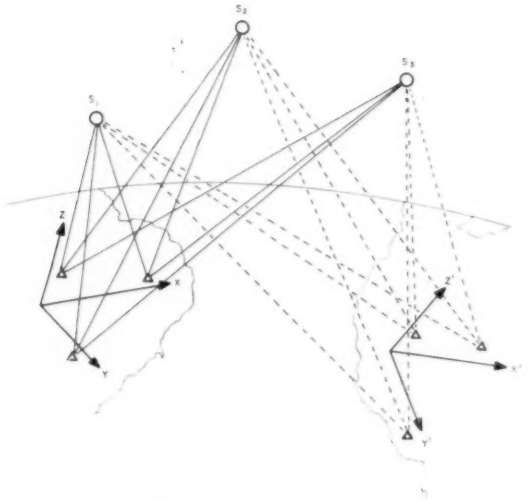


FIG. 4—Intercontinental geodetic ties.

between South America and Africa is around 3,000 km., where 1 km. is equivalent to 0.621 mile.

Suppose then that we make simultaneous distance measurements from a group of stations on each coastal area upon the orbiting satellite. From a number of simultaneous and non co-linear observations the separate geodetic systems of reference may be correlated. (See figure 4.)

The difficulties of simultaneous observations while tracking a body travelling at great speed are considerable. However, the artificial satellite programme offers a great opportunity in the solution of earth survey problems. Once a synchronized observation system is arranged, satellites will provide a continuing opportunity for observations. Correlation of the maps of separate continents will solve a problem that has eluded practical geography since its beginning.

The scientific significance of satellites for geodetic research has been recognized by the U.S. National Academy of Sciences. As a result the Geodesy Committee of Space Science Board has been formed. In the committee's opinion the following geodetic objectives could be advanced through satellite observations:

(a) Correlation of position of widely separated geodetic datums. An accuracy of 30 metres is desired and believed possible to obtain.

(b) An evaluation of the size and shape of the earth.

(c) The determination of the gravity field of the earth.

(d) The position of the gravitational centre of the earth.

Presently, extensive studies related to geodetic satellites are being carried out in the United States. They are indications that a special satellite for geodetic applications will become a reality in the not-too-distant future.

It may be mentioned that non-geodetic satellites have already yielded valuable information about the flattening of the earth as being 281.3. This figure is in exact agreement with Krassowski's flattening number (see Table I). Recent orbital analysis of Vanguard, 1958 $\beta 2$ indicates that the earth has a pear shape, with 15 metres of undulation in the geoid.

CANADIAN SCIENTISTS REPORT—XIX

THE OTTAWA MERIDIAN CIRCLE

By E. G. Woolsey
Dominion Observatory, Ottawa, Ontario

Introduction

The object of this article is to acquaint the reader with the work in positional astronomy being carried on in Canada. Positional Astronomy is a branch of astronomy with direct practical applications, for it is the determination of the accurate positions of stars which is essential for time, surveying and navigation. A common misconception is that a star's position may be considered definitely known once sufficient observations have been made to include it in a catalogue of stellar positions. Such is not the case for the stars are not fixed but move in relation to each other. Modern timekeeping and surveying demand continuing accurate knowledge of star positions.

In addition to these practical applications positional astronomy provides the essential foundation for the study of the dynamics and evolution of the solar system. The astronomers are mainly interested in the small apparent motions of the stars. These small motions provide information about the distances to the nearest stars, the motion of the sun through space, motions of various star streams and other such studies.

The Telescope

The instrument most commonly used in this work is called a meridian circle. It is designed to determine both the right ascension and declination of a star, or other heavenly body, at its time of transit over the meridian. The instrument is a combination of a transit instrument and a graduated vertical circle.

The transit instrument is defined by Chauvenet as: "An instrument for determining the instant of a star's passage through any given vertical plane; or the time of a star's transit over any given vertical circle. For this purpose, it is necessary that the motion of the telescope be confined to the vertical plane; and this is effected by attaching the tube to a horizontal axis and perpendicular to it, so that by revolving the instrument about this axis the principal sight-line of the telescope describes a plane passing through the zenith." Although by this definition the instrument can be mounted in any vertical plane it is usual to mount it to trace out the plane of the meridian.

The right ascension of a star is obtained by determining its time of transit over the meridian. This is done by following the image of the star with a web or reticule while electric contacts register on a chronograph the instants that the star is at known intervals from the centre line.

The declination of a star is determined by reading the graduated circle. In practice this is accomplished in two steps. The circle is set and its exact position determined by microscopes or cameras rigidly attached to the pier that supports the main axis. Then during transit, a micrometer, mounted in the eye end of the telescope, is used to make several measures of the distance the star image is from the centre of the field.

The first telescope of this type was built by Roemer of Copenhagen in 1704, but it was not until after 1830 that the advantage of this type of instrument was realized. By having the circle attached to the axis, and by using microscopes mounted at the ends of diameters, it was possible to determine the errors of the graduated circle instead of relying on the maker's skill for its accuracy. Again, since the instrument axis is made symmetrically, the axis may be reversed in the pivots. During the nineteenth century the instrument was developed so that it could determine all its own scales and produce a catalogue of star positions independent of observations made with other instruments.

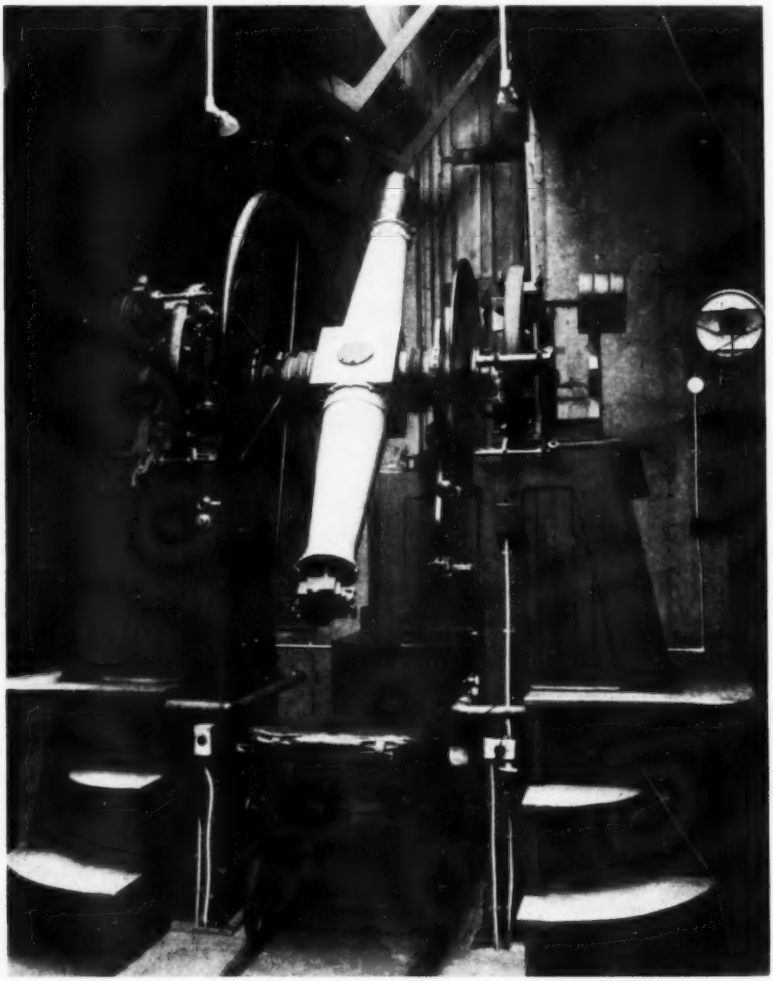
The Ottawa Meridian Circle

The Ottawa meridian circle is a typical example of this type of instrument. It was built by Troughton and Simms of England and was delivered on October 28, 1907. It is housed in an extension of the west wing of the Dominion Observatory. The telescope is of average size and is probably best described by a photograph. It has a 6-inch objective and an 85-inch focal length. The axis is 45 inches between the pivots and the graduated vertical circles are 36 inches in diameter. The graduations are engraved on a silver inlay set into the circles and every five minutes of arc is marked. The circle settings, formerly read visually, are now registered by four cameras operated electrically.

A more complete description of the instrument was given by R. Meldrum Stewart in *Reports of the Chief Astronomer* for the years 1908, 1909, 1910 and 1911. In these reports he discussed the difficulties overcome in mounting the instrument and getting it into operation. A description of the cameras and the method of reading the film are described in the R.A.S.C. JOURNAL, vol. 45, p. 199, 1951.

Meridian Astronomy reached its zenith at the turn of the century; but owing to the large number of observations required and the resulting laborious calculations it has lost its popularity with the Universities. As a result less than one-third of the meridian circles in the world are still in operation today. However, the demand for observations and improve-

ment of accuracy still continues and this branch of astronomy is now carried on at National Observatories such as the Dominion Observatory in Ottawa.



The Ottawa Meridian Circle telescope pointing south of the zenith. The setting wheel is on the east side and the clamp is on the west. Cameras for photographing the circle position are mounted permanently on the east pier. The eyepiece micrometer box attached to the lower end of the telescope provides readings in the two co-ordinates. At the other end is the dew cap which protects the objective.

In Ottawa from two to four astronomers have been employed full time on this work since 1910. During this period the instrument has been in operation almost every clear night and over 300,000 observations have been made. Until 1950 most of the astronomer's time was spent in observing and in reduction of the observations.

Since 1950 electronic computers have relieved the astronomers of much of the tedious reductions and time has been available to publish all results and to make a re-examination of the instrument. It was found that the accuracy of the observations was lagging behind that obtained with modern meridian circles. Consideration was given to replacing it, but little seemed to be gained by building another meridian circle since this type of instrument appears to have reached its limit of accuracy.

Our problem is well summarized by J. B. Irwin: "Meridian astronomers should not be content with the performance of their instruments until such time as they measure up to the performance of the P.Z.T. at least at declinations near the zenith. It is certain that the troubles are in the observing methods and the instruments and are not in the seeing except possibly for extremely large zenith distances."

Early in 1953 it was decided that steps should be taken to replace the present meridian circle. On May 1 a meeting was held with Dr. C. S. Beals and all members of the Positional Astronomy Division at which it was decided to investigate the possibilities of building a Mirror Transit as suggested by Dr. R. d'E. Atkinson in *Monthly Notices*, vol. 107, 1947 and H. H. Turner in *Monthly Notices*, vol. 54, 1894. This new instrument is at present under construction and it is expected that preliminary tests will soon be made on the parts already assembled. The new instrument has been designed to overcome many of the weaknesses of the meridian circle and efforts are being made to make observing automatic and have all routine calculations done by electronic computers. It will, however, be a few years before the instrument can be in operation.

Observing Programmes

With the design of the new instrument well advanced, and at the stage where it will soon occupy our whole interest, it seems appropriate to look at the accomplishments of the old instrument.

In addition to its normal work of determining star positions, the meridian circle was used from 1911 to 1929 for determining the correct time. In 1929 it was superseded in the time service by a 3-inch Cooke Broken Transit. Although the Cooke instrument did not have as good internal consistency of observation it gave a more uniform night-to-night correction. In 1951 the Cooke telescope was in its turn superseded by the photographic zenith telescope (P.Z.T.).

First Programme. The first programme undertaken with the meridian

circle was the improvement of the positions of stars required for the astronomical determinations of latitude and longitude in Canada. The list was extracted from *A Catalogue of Stars for Latitude Observations on Dominion Lands Surveys* prepared by the Surveyor General of Canada.

One must appreciate that at this time no generally accepted catalogue of star positions existed. It was customary for each country to prepare a star list to meet its own requirements, and to improve the knowledge of the star positions by observing with a meridian circle.

Observation of this list was carried on from 1911 to 1923. Although the observing terminated in 1923 the necessary reductions and studies continued over the next ten years. Unfortunately final discussions were interrupted by staff restrictions and the Second World War so that publication of the results was delayed until 1949.

Backlund-Hough Programme. The second programme undertaken was far more ambitious than the first. It was decided to observe each star of the Backlund-Hough list four times, along with observations of the sun, moon and planets, then to interchange the eye end and object glass and re-observe the list in the same manner.

The Backlund-Hough stars were prepared as a provisional catalogue of fundamental stars. It was approved by the Comité des Cartes du Ciel in Paris in 1910 and was published in the *Connaissance des Temps* for 1914. At the meeting of the International Astronomical Union in Rome in 1922 meridian circle observers were asked to give preference to the observing of these stars.

It was considered at that time that the number of stars in the fundamental catalogue, for which daily or ten-day places were published, should be about 3,000. Accordingly this list was drawn up to include all the fundamental stars of the three existing fundamental systems, namely, Auwers *Fundamental Catalogue* (NFK), Boss' *List of Standard Stars* and Newcomb's *Catalogue of Fundamental Stars*, and additional stars to bring the number to about three thousand. During the succeeding years this list of stars has been observed by most national observatories.

The observations of the first part of this B.H. star programme were completed in 1935 and the eye end and object glass were interchanged. Unfortunately, owing to staff reduction, it was not possible to complete the second half of the programme in the same manner. The observations of the sun and planets decreased and finally ceased in 1937. For this reason it was decided to break the programme in two at 1935 and to complete the observations on the stars by 1950.

Since the current calculations on this work had been kept up-to-date and a pattern for applying the necessary corrections had been developed, there was no long delay in publishing the results. The observations for

the years 1923 to 1935 were published in 1952 and those for the years 1935 to 1950 in 1954.

It was rather fortunate that this programme was divided, for, by treating the observations for 1923 to 1935 as a unit, it was possible to make them available to Dr. H. R. Morgan of the U.S. Naval Observatory for his catalogue N30.

PZT Programmes. Between 1950 and 1953 a short differential programme was undertaken. The object of this was to provide improved positions of stars suitable for the photographic zenith telescopes at Ottawa; Herstmonceux, England; and Richmond, Florida, U.S.A. It was also intended to familiarize the new staff members with the meridian circle work and leave time to devote to the publication of previous observations.

During this period the instrumental corrections were again investigated and methods were sought to reduce the errors of observation. With the assistance of college students in the summer period, and by sending part of the work out for calculation, the past observations have all been published. All observations on fundamental stars up to the end of 1953 have been made available to Dr. A. Kopff for his revision of the *Fundamental Catalogue*, and observations for the period 1950 to 1953 were published in 1957.

FK3 Supplement Programme. The current observing programme which was started in 1954 includes the observations of the FK3 Supplementary Stars of the northern sky. The present *Fundamental Catalogue* (FK3) consists of 1,535 stars for which ten-day places are published. The FK3 *Supplement* is a list of 1,987 stars, 1,142 in the northern hemisphere and 845 in the southern, prepared by Dr. A. Kopff of the Recheninstitut and published in the *Berliner Jahrbuch* 1954 and 1956. This list was prepared for two reasons: firstly to increase the number of stars for geodetic purposes and secondly to provide a better distribution of the stars of the FK3 to assist in the determination of the fundamental constants. With the inclusion of this list the FK3 catalogue will be increased to over 3,000 stars which should extend its usefulness greatly.

The formal request for the observation of these stars was published in the *Transactions* of the International Astronomical Union, vol. IX, 1955, as recommendation 18 of Commission 4. At present five observatories are already co-operating in this important task and more will follow as soon as their present commitments are completed.

AGK3R Programme. The Assembly of the International Astronomical Union, held in Dublin in 1955, approved a plan for new photographic observations of the AGK stars in the northern sky and meridian observations of the AGK3 Reference stars.

The AGK list includes most of the stars down to 9th magnitude. It forms the first international survey of the whole sky and was done visually from about 1875 to 1890 using meridian circles. For this survey each meridian circle was allotted a zone in the sky.

In 1930 a re-observation of the same stars was undertaken by the Russian and German observatories. Although this survey was accomplished photographically it employed meridian circles to determine the position of the reference stars for each plate. For this undertaking three astrographic telescopes and nine meridian circles were used, and the published catalogue of the star positions is known as the AGK2.

To carry on the name sequence, the third catalogue of the AGK stars will be known as the AGK3. It is to be accomplished in the same manner as the AGK2 but with more countries participating.

The meridian circle observations of the reference stars for this programme are being made at twelve observatories including Ottawa. The collection of the observations and the publication of the catalogue of reference stars is being done at the United States Naval Observatory. The Ottawa portion of the international programme commenced in 1956 and is intended to be completed by the end of 1960.

When the AGK3 is completed it will provide the necessary information for many investigations. The AGK3 and AGK2 together should provide a uniform system from which a first approximation to good proper motions can be obtained. With this first approximation the original *Astrographic Catalogues* of 1890 will provide a better approximation to the motion of the stars. Again with improved proper motions further studies can be made of the motions of the star streams and other fundamental problems.

Conclusion

During its half century of operation the Ottawa meridian circle has made a contribution in the field of Positional Astronomy. Already Dr. H. R. Morgan has used our first two observational catalogues in his general *Catalogue of 5,268 Standard Stars*, more commonly known as N30. Our first four catalogues are being used in the revision of the fundamental catalogue and our present observing is assisting the new international survey of the heavens and the extension of the fundamental catalogue.

It is not intended to undertake any future programmes of observation with the present meridian circle. It will be kept in operation until present commitments are completed and thereafter only long enough to compare with the new instrument.

METEOR NEWS

By Peter M. Millman

National Research Council, Ottawa

Photographic Meteor Spectra (Appendix 7)

Each year in Meteor News I have attempted to bring up-to-date the world listing of meteor spectra. Reference to the previous listings will be found in the Journal, vol. 52, p. 275, 1958. This current appendix is a large one, both because interest in this type of astronomical photography is growing, and because I am able to include here the recent spectra secured in the U.S.S.R. and Czechoslovakia. I would like to thank the following astronomers for their co-operation in sending me lists of spectra and other relevant information concerning this subject: I. S. Astapowitsch, Odessa Obs., U.S.S.R.; A. M. Bakharev, Stalinabad Obs., U.S.S.R.; W. A. Feibelman, Pittsburgh, Pa., U.S.A.; I. Halliday, Dominion Obs., Ottawa; E. N. Kramer, Odessa Obs., U.S.S.R.; K. A. Liubarskii, Ashkabad Obs., U.S.S.R.; R. E. McCrosky, Harvard College Obs., U.S.A.; J. Rajchl, Ondrejov Obs., Czechoslovakia; H. B. Ridley, Barnes, S.W.13, England; J. A. Russell, University of Southern California, U.S.A.; B. Valnicek, Ondrejov Obs., Czechoslovakia.

While an attempt is made to assign numbers to meteor spectra in chronological order, this is not always possible, as information concerning them is often delayed in reaching me. Hence in this appendix, though it is primarily concerned with the spectra photographed in 1958, 25 records from earlier years are included. In addition to these, 63 meteor spectra were secured in 1958, nearly twice as many as have been taken in any single previous year. This brings the world total up to 318 where each meteor is counted only once, though in many recent cases several spectra have been secured of the same object.

The distribution among countries of these meteor spectra is tabulated.

METEOR SPECTRA (1897–1958)

Canada	140
U.S.S.R.	82
U.S.A.	69
England	13
Czechoslovakia	12
Germany	1
Sweden	1
	318

Details of spectra previously unlisted appear in Table I, the column headings being self-explanatory.

TABLE I

LIST OF PHOTOGRAPHIC METEOR SPECTRA (APPENDIX 7)

No.	Date y	m	d	U.T. h	m	s	Shower	Location (observatory)	Ref.
231	1953	8	12				P	Simferopol, U.S.S.R.	
232		8	12				P	" "	
233		8	12				P	Kuchino, U.S.S.R.	44
234		8	13				P	" "	44
235	1955	8	13				P	Ashkabad Obs., U.S.S.R.	
236		10	16				O	" "	
237		10	18				O	" "	
238		10	18					" "	
239		10	26				O	" "	
240	1956	8	4				P?	Ondrejov Obs., Czechoslovakia	46
241		8	7				P	Odessa Obs., U.S.S.R.	
242		8	8					" "	
243		8	9				P	" "	
244		8	11				P	" "	
245		8	11					Simferopol, U.S.S.R.	
246		8	11				P	" "	
247		8	11				P	" "	
248		8	11				P	" "	
249		8	11				P	" "	
250		8	11				P	" "	
251		8	11	18	00	*	P	Alma Alta Obs., U.S.S.R. (V.A.G.O.)	
252		8	12	21	43	58†	P?	Ondrejov Obs., Czechoslovakia	46
253		10	7					Odessa Obs., U.S.S.R.	47
254	1957	1	4				Q?	Simferopol, U.S.S.R.	
255		8	6	00	35	*		Odessa Obs., U.S.S.R.	
256	1958	1	19	06	45	17		Springhill, Ont. (N.R.C.-D.O.)	
257		2	26	03	37	42		" " "	
258		3	28	01	18	06		" " "	
259		4	13	08	56	*		Meanook, Alta. (D.O.)	
260		5	05	07	52	49		Springhill, Ont. (N.R.C.-D.O.)	

TABLE I (*continued*)

LIST OF PHOTOGRAPHIC METEOR SPECTRA (APPENDIX 7)

No.	Date y	m	d	U.T. h	m	s	Shower	Location (observatory)	Ref.
261	1958	5	12					Ashkabad Obs , U S.S.R.	
262		5	12					" "	
263		5	15					" "	
264		8	7	16	26			Stalinabad Obs., U.S S.R.	
265		8	8				P	Ashkabad Obs., U.S.S.R.	
266		8	10	07	47	02	P	Pittsburgh, Pa.(W.A Feibelman)	
267		8	11	09	24	40	P	Meanook, Alta. (D.O.)	
268		8	11	20	36	25†	P?	Ondrejov Obs., Czechoslovakia	
269		8	11	21	05		P	Simferopol, U.S.S.R.	
270		8	11	21	08		P	" "	
271		8	11	22	20	*	P	" "	
272		8	12	06	20	15	P	Springhill, Ont. (N.R.C.–D.O.)	
273		8	12	06	39	25	P	" " "	
274		8	12	06	42	00	P	Mt. Palomar, Calif. (U.S.C.)	
275		8	12	08	01	15	P	Meanook-Newbrook, Alta. (D O.)	
276		8	12	08	40	*	P	Newbrook, Alta. (D.O.)	
277		8	12					Ashkabad Obs., U.S.S.R.	
278		8	12					" "	
279		8	12	22	15	*		Stalinabad Obs., U.S.S.R.	
280		8	12	22	30	*	P	Odessa Obs., U.S.S.R.	
281		8	13	00	35	*	P	" "	
282		8	13	05	33		P	Newbrook, Alta. (D.O.)	
283		8	13	06	31	24	P	Meanook-Newbrook, Alta.(D.O.)	
284		8	13	07	59	46	P	Meanook, Alta. (D.O.)	
285		8	13	08	57	50	P	Meanook-Newbrook, Alta.(D.O.)	
286		8	13	09	37	36		Meanook, Alta. (D.O.)	
287		8	13	09	42	05	P	" "	
288		8	13	22	14	06		Ondrejov Obs., Czechoslovakia	
289		8	13	22	35		P	Simferopol, U.S.S.R.	
290		8	13	22	40	*	P	" "	
291		8	13	22	40	*	P	Simferopol, U.S.S.R.	
292		8	13	22	40	*	P	" "	
293		8	14					" "	
294		8	15	07	30			Newbrook, Alta. (D.O.)	
295		8	15	23	26		P	Barnes, S.W. 13 (H. B. Ridley)	
296		8	16					Ashkabad Obs., U.S.S R.	
297		9	7					" "	
298		9	8	18	55	*		Odessa Obs., U.S.S.R.	
299		9	9	19	55	*		" "	
300		10	13	03	16	31		Springhill, Ont. (N.R.C –D.O.)	
301		10	17	08	38	53	O	Sacramento Pk., N.M. (H.C.O.)	
302		10	17	07	49		O	Newbrook, Alta. (D.O.)	
303		10	21	09	19	15	O	" "	
304		10	21	10	18	37	O	Sacramento Pk., N.M. (H.C.O.)	
305		10	21	11	11	24	O	Meanook, Alta. (D.O.)	
306		10	21	12	39	20	O	Newbrook, Alta. (D.O.)	
307		10	21				O	Ashkabad Obs. U..S.S.R.	
308		10	21				O	" "	
309		12	12	08	54	30	G	Springhill, Ont. (N.R.C –D.O.)	
310		12	13	00	21		G	Barnes, S.W. 13 (H. B. Ridley)	

TABLE I (*concluded*)

LIST OF PHOTOGRAPHIC METEOR SPECTRA (APPENDIX 7)

No.	Date			U.T.			Shower	Location (observatory)	Ref.
	y	m	d	h	m	s			
311	1958	12	13	09	51	13	G	Sacramento Pk., N.M. (H.C.O.)	
312		12	14	05	21	56	G	Springhill, Ont. (N.R.C.–D.O.)	
313		12	14	05	50	30	G	Pittsburgh, Pa.(W.A. Feibelman)	
314		12	14	06	46	03	G	Springhill, Ont. (N.R.C.–D.O.)	
315		12	14	06	58	55	G	" " "	
316		12	14	07	34	20	G	" " "	
317		12	14	09	01	04	G	" " "	
318		12	17	06	43	25		" " "	

Abbreviations:

G Geminid
O Orionid
P Perseid
Q Quadrantid

D.O. Dominion Observatory
N.R.C. National Research Council
H.C.O. Harvard College Observatory
U.S.C. University of Southern California
V.A.G.O. All-Union Astro-geodetic Society

*Indicates middle of exposure
†Indicates start of exposure

REFERENCES

43. Bakharev, A. M. *Trans. Stalinabad Ast. Obs.*, vol. 3, p. 73, 1950 (Spectrum 53).
44. Astavin-Razumin, D. L. *Bul. V.A.G.O.*, no. 19 (26), p. 36, 1956 (Spectra 233, 234).
45. Bumba, V. and Valnicek, B. *Bul. Ast. Inst. Czechoslovakia*, vol. 7, p. 18, 1956 (Spectrum 181).
46. Fritzova, L. and Rajchl, J. *Bul. Ast. Inst. Czechoslovakia*, vol. 9, p. 148, 1958 (Spectra 240, 252).
47. Kramer, E. N. *Ast. Cir. Acad. Sci. U.S.S.R.*, no. 195, 1958 (Spectrum 253).
48. Astapowitsch, I. S. "Meteoric Phenomena in the Earth's Atmosphere", State Publishing House, Moscow, 1958.
49. Russell, J. A. *Sky and Telescope*, vol. 18, p. 549, 1959 (Spectra 103, 118, 124, 198, 199).
50. Millman, P. M. and Cook, A. F. *Astrophy. Jour.*, vol. 130, p. 648, 1959 (Spectra 132, 134).

In Canada during 1958 regular programmes of meteor photography were carried out at the three meteor observatories at Meanook and Newbrook, Alta. and at Springhill, Ont. Spectra of 29 meteors were secured, the personnel carrying out these observations being essentially the same as in 1957. In general meteor spectrophotography in other countries was organized by the astronomers listed above. A large number of meteor spectra have been photographed recently in the U.S.S.R., 24 being taken in 1958. Reference should be made here to the list of meteor

spectra of the U.S.S.R. appearing on pages 309–312 of Astapowitsch's new book on meteors, which I reviewed in the August JOURNAL. In this list each individual photograph is numbered rather than each meteor.

I should like in particular to call attention to the work of two experienced amateur astronomers, one in England the other in the U.S.A. Mr. H. B. Ridley (the initials W. B. appearing in previous lists are incorrect) added 2 spectra in 1958, bringing the total for his programmes up to 13. Mr. Ridley was the first to photograph the auroral green line at 5577 A., as it appeared in Spectrum 186, taken in August 1955, but he did not identify it at that time. He wrote me, however, on April 12, 1956, and remarked concerning Spectrum 186 that "the spectrum is interesting because the 'leader' line fades out just as the others are coming up to maximum brightness". The line referred to is the auroral green line and this is a very good example of the type of valuable contribution to science for which the amateur astronomers of the British Isles are noted.

A new contributor to the spectrum list in 1958 is Mr. W. A. Feibelman, 1063 Findley Dr., Pittsburg 21, Pa. Excellent auroral pictures by Feibelman have appeared on several occasions in *Sky and Telescope*.

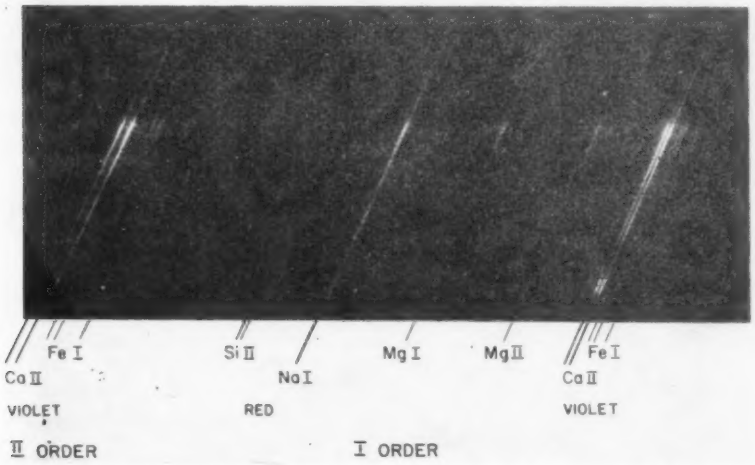


FIGURE 1—Spectrum No. 266, photographed by Mr. W. A. Feibelman at Pittsburgh, Pa., using a Bausch and Lomb replica transmission grating. The meteor was a Perseid of visual magnitude −1 and is moving down in the above record. It appeared at $07^h\ 47^m\ 02^s$ U.T. on Aug. 10, 1958, leaving a train of 4 sec. duration. The ionized calcium behaves typically, showing greater relative strength at the end of the trail.

He has photographed 2 meteor spectra with a transmission grating. One of these is reproduced in figure 1. Mr. Feibelman kindly forwarded his spectra to me for measurement and with his permission the resulting wave-lengths and multiplet identifications are listed in Table II. The multiplet numbers used are from the table by C. E. Moore in *Princeton Observatory Publication*, no. 20, 1945.

As a result of new information received there are a number of small revisions to some of the previous appendices published, in particular in

TABLE II

PITTSBURGH METEOR SPECTRA

Spectrum No. 266 August 10, 1958 (7.47.02 UT) Perseid Meteor, vis. mag. −1			Spectrum No. 313 December 14, 1958 (5.50.30 UT) Geminid Meteor, vis. mag. −2		
λ	Multiplet Identification		λ	Multiplet Identification	
3570.5	Fe I (24)	Fe I (23)			
3615.8		Fe I (23)			
3720.1	Fe I (5)	Fe I (21)			
3734.0	Fe I (21)	Fe I (5)			
3762.0	Fe I (21)				
3795.3	Fe I (21)	Fe I (22)			
3833.2	Mg I (3)	Fe I (20)	3831.0	Mg I (3)	Fe I (20)
3856.9	Si II (1)	Fe I (4)	3869.0	Fe I (4)	Fe I (20)
3933.6	Ca II (1)		3933.8	Ca II (1)	
3968.6	Ca II (1)		3968.6	Ca II (1)	
4040.5	Fe I (43)				
4230.5	Ca I (2)				
4319.4	Fe I (42)				
4386.4	Fe I (41)	Fe I (2)			
4426.5		Fe I (2)			
4480.9	Mg II (4)	Fe I (2)			
4561.9	Mg I (1)				
5050.2	Si II (5)				
5104.8	Fe I (1)				
5177.3	Mg I (2)	Fe I (1)	5177.3	Mg I (2)	
5892.5	Na I (1)		5892.5	Na I (1)	
6348.4	Si II (2)				
6370.1	Si II (2)				

Appendix 4. In general reference numbers have not been changed. I am now compiling a complete revised list of the meteor spectra of the world, and an international atlas of the most representative and significant meteor spectra. It is hoped that this will be ready before the 1961 meeting of the I.A.U. in the U.S.A. I would like to be informed of all spectra photographed in 1959, and of any secured before this year which have been omitted from the published lists.

NOTES FROM OBSERVATORIES

Dominion Observatory, Ottawa, Ontario

Positional Astronomy. Additional parts have been secured for the new Mirror Transit Telescope and at the moment measurements are in progress to determine the stability of the 11-inch fuzed quartz flat. Footings have been poured for the new building to house the P.Z.T. which, since its arrival in 1951, has been mounted temporarily in the transit room. Transmission of precise time signals via CHU has been improved with a new transmitter on 14670 kc.

Stellar Physics. Construction of the radio telescope near Penticton, B.C., continued during the summer, and the 84-foot dish was lifted into place on the tower in September. It is expected that the telescope and associated buildings will be completed during the fall permitting detailed tests and calibrations of the instrument to begin. The radio observatory is to be known as the Dominion Radio Astrophysical Observatory. Photometric light-curves have been completed for about 250 solar flares observed during I.G.Y. and which showed a correlation with 10-cm. radio bursts observed by N.R.C. Meteor observations at Meanook and Newbrook, Alta., were favoured by good weather during the Perseid shower. Preliminary studies indicate that useful results were obtained with the Super-Schmidt telescope and the meteor spectrographs. Poor weather severely restricted observations of the Perseids at Ottawa.

Geomagnetism. Magnetic survey parties operated in Western Canada and in the Ellef Ringnes Island area of the Arctic as well as at Alert, North Ellesmere Island. The results of these surveys will be incorporated in magnetic charts and employed in analyses of the earth's magnetic field. Recording proton precession magnetometers were constructed and horizontal gradient measurements made in Alberta, based on Meanook Magnetic Observatory. An intercomparison of magnetic standards was made between Meanook and seven magnetic observatories situated in Great Britain, France, Denmark and Sweden. An additional magnetic observatory building was constructed on the grounds of the Dominion Astrophysical Observatory at Victoria and new recording variometers installed.

Gravity. During the current year pendulum observations are being made to connect Potsdam, Germany, Rome, Italy, Paris, France and Teddington, England, with Ottawa. These measurements are expected to make an important contribution to establishing a homogeneous world

system of first order gravity stations required for geodetic studies. The measurements will also provide a check on the consistency of experiments to determine the absolute value of gravity which are being carried out or have recently been completed at these sites.

Seismology. Development of a three component seismograph designed to record earthquake movements on magnetic tape continued with a change of emphasis away from the seismometer itself, towards the equipment for recording and playing back the electrical analogues of the earth movement. Much of the new field equipment has also been tested, and the process of fitting out a recording vehicle is well advanced.

Personnel. Distinguished visitors to the Observatory have included R. L. Corke of the British Post Office, Drs. F. P. Scott and G. van Herk of the U.S. Naval Observatory, and Abdul Majid Khan, a Columbo student from Pakistan. A number of the staff were at the Toronto meetings of the American Astronomical Society. Dr. Luise Herzberg was in Europe during the summer and attended several scientific meetings. Dr. J. H. Hodgson has returned from a year in Paris and Copenhagen where he investigated "S" waves, with particular reference to the information they might give concerning the mechanism of earthquakes. Dr. K. Whitham is on leave of absence for a year and, under the sponsorship of the United Nations, is conducting a geomagnetic survey of British East Africa. Miss Anne B. Cook visited scientific stations in Europe and East Africa this summer, examining earth-current and magnetic installations and making comparisons of magnetic standards. Several staff members appeared on the T.V. programme "Focus on Ottawa" which originated from the D.O. on September 8 and was televised over the C.B.C. coast to coast network. Staff changes include the following: Dr. J. L. Locke has moved to Penticton to be in charge of the radio observatory during its first two years. A. A. Griffin has returned to the D.O. after spending eight years at the Newbrook Meteor Observatory. Mr. and Mrs. A. A. Onhauser have transferred from the Geomagnetic division at Ottawa to the Agincourt Magnetic Observatory, and A. E. Evans was transferred from Agincourt to Meanook Magnetic Observatory. Miss Joan Stewart resigned from the staff to marry Dr. Allan F. Cook of the Harvard Observatory, and will reside in Cambridge, Mass. Miss Zelma Moore, R. A. Costanzo, T. J. Mousseau and D. K. Smith resigned in order to pursue further studies. Among those recently appointed to the staff are: Mrs. Barbara Dell, Positional Astronomy; A. R. Hamilton, Stellar Physics, at Penticton; Miss Catharine Sayn-Wittgenstein and W. Darker with the division of Geomagnetism; and R. K. McConnell with the Gravity division.

MIRIAM S. BURLAND

VARIABLE STAR NOTES

By Margaret W. Mayall

The American Association of Variable Star Observers, Cambridge, Mass.

For many years, the A.A.V.S.O. has published annual predictions of approximate dates of maxima and minima for the most regular of the variable stars on the A.A.V.S.O. programme. These predictions are useful for observers who try to make the most efficient use of their observing time and equipment. An observer with a small instrument should not waste his time trying to find a long-period variable when it is near minimum and far below his limiting magnitude. Similarly, an observer with a very large telescope should not waste his equipment on a variable near maximum and bright enough to be seen in binoculars.

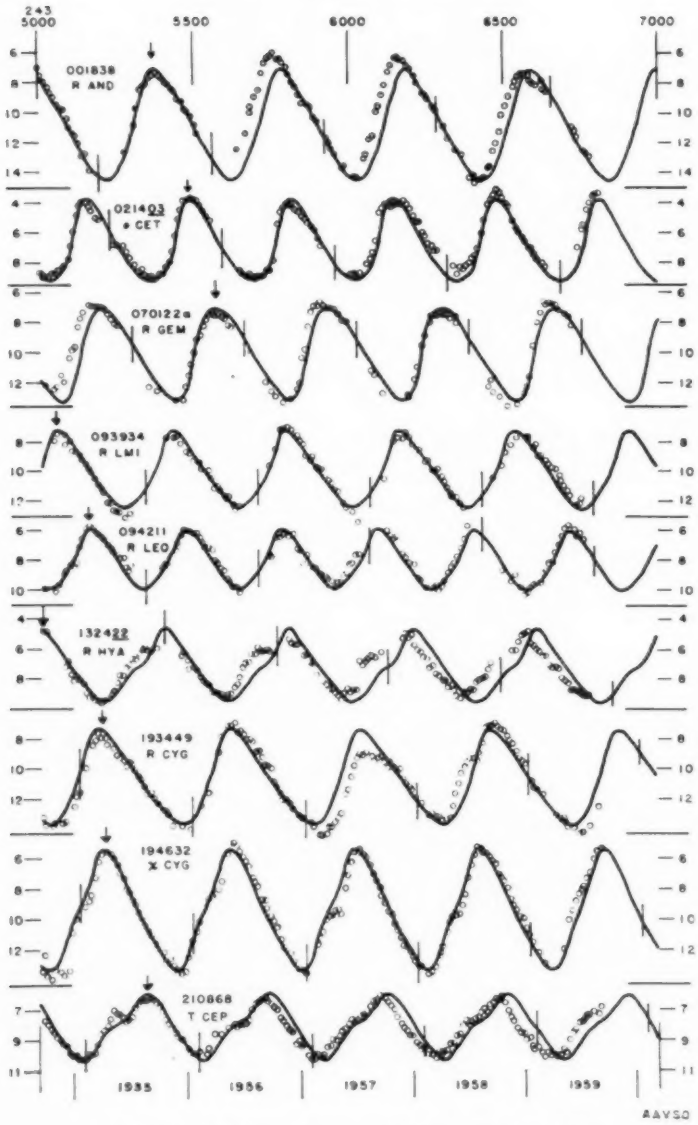
The predictions are also used as a guide in setting up observing programmes by many of our large observatories. They are especially useful for the researcher who wishes to study the spectrum of a variable during certain phases of its light variations. An outgrowth of this use was the suggestion by Dr. Paul Merrill that a visual representation of the predictions for several years in the future would be useful for the spectroscopist.

TABLE I

Variable		Mag.	Period	Spectrum
001838	R And	7.0–14.6	409 days	S6e
021403	o Cet	3.4– 9.3	332 ,,	M5e–9e
070122	R Gem	7.1–13.5	370 ,,	S3, 9e–S6, 9e
093934	R LMi	7.1–12.6	372 ,,	M7e–8e
094211	R Leo	5.8–10.0	313 ,,	M7e–9e
132422	R Hya	4.5– 9.5	386 ,,	gM7evS
193449	R Cyg	7.5–13.9	426 ,,	S3, 9e–S6, 8e
194632	chi Cyg	5.2–13.4	407 ,,	S7, 1e–S10, 1e
210868	T Cep	6.0–10.3	390 ,,	M5e–7e

Table I lists the stars used for the first set of curves. The nine variables were selected to provide a representative group of stars scattered around the northern sky, bright enough at maximum to be observed with a high dispersion spectrograph. Four stars with late M-type spectra, characterized by strong titanium oxide bands, four of S-type, with strong zirconium oxide bands, and one, R Hydrae, which at times exhibits characteristics of both, were included in the selection.

The basis of the predicted curve for a variable is the mean light curve published in the book "Studies of Long Period Variables", by Leon Campbell (A.A.V.S.O., 1955). In order to determine the zero point for the predicted curves, the mean curve for about 6 epochs was plotted on transparent paper, and fitted over the plot of observed curves. The most recent maximum which approximated the shape of the mean curve was selected as the zero maximum. The curves shown in the figure were plotted for the 2,000-day interval from J.D. 2,435,000 to 2,437,000 (1955–1960). The zero maximum for each variable is indicated with a small arrow.



Predicted and observed curves for 9 long-period variables.

The set of curves reproduced here was made up early in 1956. The solid curve is the predicted mean curve, and the open circles are observed 10-day mean values. The observed points through August 1959 have been entered on the plot to show the agreement (and disagreement) between the observed curve and the mean curve.

The vertical line drawn through the light curves at yearly intervals indicates the time the variable is near conjunction with the sun, and is difficult or impossible to observe.

For the star R Andromedae, the three maxima following the adjusted zero maximum were 32, 20 and 18 days early, respectively. The maxima of o Ceti differed more in shape and brightness than in time. The very broad maximum of 1957–1958, followed by a brighter than normal minimum, has been discussed in these Notes (vol. 52, no. 5, vol. 53, no. 1).

The period of R Hydrae has been decreasing systematically throughout the years since its discovery in 1704 by Maraldi. In the early eighteenth century, R Hydrae was considered to have a period of about 500 days. In 1948 Leon Campbell called the period 407 days, and in the 2nd edition of the *General Catalogue of Variable Stars* (1958) a period is listed as 386 days. The mean curve in the figure is plotted assuming Mr. Campbell's period of 407 days. The observed points show that the period at the present time must be 20 to 30 days shorter.

R Cygni had a deep minimum in 1957, followed by a slow rise to a very shallow maximum. For many years the period of T Cephei seemed to be lengthening, but from the recent observations it appears to be growing shorter again.

A.A.V.S.O. Nova Search Report (From George Diedrich, Chairman): Observations of Nova Search Areas were made by the following 25 observers for a total of 725 area-nights for the two months reported. Each name is followed by the number of observations made in May and then June 1959: Robert Bishop–0, 16; James Breckinridge–0, 6; Buddy Brown–16, 27; I. Debono–4, 3; Frank DeKinder–17, 5; DeLorne Diedrich–12, 8; George Diedrich–11, 12; C. L. Drolet–4, 17; Paul Evans–0, 57; Kenneth Fuller–33, 27; Geoffrey Gaherty, Jr.–10, 7; Charles Giffen–16, 6; William Isherwood, Jr.–18, 17; Walter Kaminski–8, 0; Friend Kierstad, Jr.–2, 3; Peter Leate–0, 20; Mike Muench–15, 0; Howard Nightingale–51, 24; D. W. Orchiston–70, 96; Thomas Osypowski–2, 3; G. A. Spencer–2, 7; F. Traynor–11, 3; George Wedge–16, 6; Jim Wright, Jr.–0, 8; D. Zorgo–15, 14.

In addition the following 3 sets of April observations did not appear in the last summary: K. H. Doyle–12; Charles Giffen–2; P. Glaser–2.

Two supernovae were found recently, by photography, by professional astronomers. They were both in other galaxies, needless to say. To find the next nova (super or regular) just remember our password: *Keep Looking.*

In spite of the perennial "bad weather" observers always complain about, a very satisfactory number of observations was received during the months of July and August 1959. In August we received observations from 81 observers, the largest number since 1951 when these notes were started in the JOURNAL. The total number of observations received in August was also one of the highest totals of the last 8 years. The total was augmented by Sr. Roderigo de la Vega of Santiago de Chile, who sent his observations made during April to June; Mr. Michiel D. Overbeek of South Africa, who sent us his 1958–1959 observations; and by Mr. Leif J. Robinson of California, who made over 900 observations of the interesting variable, AE Aquarii, and caught several rapid increases of about three-quarters of a magnitude.

Observations received during July and August 1959: A grand total of 10,035 observations was submitted: 3,476 from 72 observers in July, and 6,559 from 81 observers in August.

Observer	July		August	
	Var.	Ests.	Var.	Ests.
Adams, R. M.	83	157	88	212
Allin, R.	...	...	32	159
Anderson, C. E.	77	103	216	370
Apolito, T.	2	3	2	3
Bales, R. M.	16	16	...	...
Ball, A. R.	8	8	20	22
Barrera, S.	...	...	4	16
Beidler, H. B.	13	17	8	8
*Berg, R.	10	20	36	46
Bicknell, R. H.	20	93	14	28
Brady, R. F.	...	...	6	6
Braune, W.	31	229	...	...
Brechlin, D.	2	8	...	...
Breckinridge, J.	25	35	2	11
Brown, A. M.	...	...	10	12
Carlisle, J. H.	2	2	1	2
Carpenter, C. B.	20	20	6	6
Celis, L.	...	...	10	86
Cragg, T. A.	158	165	231	232
Cruikshank, D. P.	1	1	...	...
Darsenius, G.	2	2	6	12
Debono, I. P.	3	3	...	...
Mourao, R. R. D.	10	42	9	15
de Kock, R. P.	126	450	118	364
de la Vega, R.	...	...	23	280
Diaz, C.	...	...	2	31
Diedrich, D.	2	4	2	3
Diedrich, G.	5	15	11	19
Dudley, R. R.	35	57	24	43
Ellerbe, J. E.	...	...	6	8
†Engelkemeir, D.	9	15	9	22
Erpenstein, O. M.	...	...	8	8
Estremadoyro, V.A	9	11	4	5
Evans, P.	2	27	...	...
Fernald, C. F.	153	237	190	497
Ford, C. B.	100	104	110	115
Fuller, K.	26	26	28	28
Giffen, C. H.	38	73	90	378
Glagola, G.	2	3	7	9
Godfrey, N. B.	...	...	25	26
Grossenbacher, R.W.	...	...	9	9
Halbach, E. A.	7	7	...	...
Hartmann, F.	118	122	123	129
Hiett, L.	8	13	4	14
Hull, A.	4	4	...	...
Hunter, T.	...	...	2	3
Hurless, C.	5	5	...	...
Hutchings, N. O.	6	6	17	19
Josephson, J.	...	...	1	1
Judd, D.	26	26	...	...
Kaminski, W. J.	13	36	52	167
Kelly, F. J.	13	13	11	11
Kindt, O. H.	6	9	11	15
Knowles, E.	...	...	2	2
Knowles, J. H.	...	...	11	26
Lacchini, G. B.	25	37	31	65
Lattey, M.	...	...	7	15
Lowder, W. M.	...	...	40	71
Martinez, A. E.	...	...	3	64
McPherson, C. A.	21	43	56	88
Miller, W. A.	4	5	17	18
Montague, A. C.	33	34	42	49
Muniz, L.	16	54	23	86
Nightingale, H. C.	3	10	...	...
Olsen, N.	...	...	1	2
Oravec, E. G.	77	91	135	231
Orchiston, D. W.	6	31	...	...
Ortiz, E. S.	...	...	2	29
Overbeek, M. D.	...	...	88	634
Parker, P. O.	51	51	12	12
Pearcy, R. E.	5	5	2	2
Peltier, L. C.	20	138	25	130
Price, R. T.	7	12	...	...
Quester, W.	8	54	...	...
Renner, C. J.	...	...	106	121
Rizzo, P. V.	11	18	25	25
Robinson, J. C.	22	29	29	44
Robinson, L. J.	1	2	46	1028
Roderick, T.	...	...	5	10
Rosalsky, R.	...	...	1	1
Rosebrugh, D. W.	13	66	14	79
Royer, R.	...	...	10	17
Rudolph, R.	33	202	...	...
Segers, C. L.	29	120	16	28
Sharpless, A. P.	...	...	9	13
Smith, G. W.	3	3	7	7
‡Smith, J. R.	...	...	5	5
Solomon, L.	1	1	7	8
Stanton, R.	14	14	12	22
Templeton, J. H.	3	3	4	4
Thomas, M. A.	2	3	...	...
Thurn, V. W.	...	...	13	13
Traynor, F.	3	6	...	...
Valdez, M.	21	39	21	34
van Zyl, L. L.	13	79	...	...
Walsh, J.	...	...	1	1
Weaverling, W.	8	15	...	...
Welker, F.	21	22	12	19
Wend, R. E.	2	2	...	...
Wilford, F.	...	...	1	1
Yamada, T.	44	93	43	105
Zellner, B.	7	7	...	...

*Plus 1^h 44^m AE Aqr †Plus 6^h ADS 8862 ‡Plus 1^h 30^m V Sge

A

American Astronomical Society, Toronto Meeting of the, 245.
Arizona Meteor Crater Controversy, The, *Matt Walton*, 162.
Astronomers Visit Four U.S.S.R. Observatories, *A. Vibert Douglas*, 74.
Astronomy, Historical Research in, *J. E. Kennedy*, 252.
Astrophysical Journal, Notice concerning the, 96.
Astrophysics, Laboratory, *R. W. Nicholls*, 109.

B

Bakos, Gustav A. (see Review of Publications).
Bateson, Frank M., Variable Star Observing in New Zealand (part 2), 1.
Bergh, Sidney van den (see Review of Publications).
Burke-Gaffney, M. W., The Halifax Planetarium, 154.
Burland, Miriam S. (see Notes from Observatories).
Buscombe, William, The Characteristics of Subdwarf Stars, 7.

C

Canadian Scientists Report, XIV, *Farquhar*, 34; XV, *Jacobs*, 85; XVI, *Nicholls*, 109; XVII, *Underhill*, 172; XVIII, *Nicholls, Watson* and *Parkinson*, 223; XIX, *Woolsey*, 264.
Chant Medal and Service Award, 232.
Characteristics of Subdwarf Stars, The, *William Buscombe*, 7.
Colgrove, Rev. W. G., Obituary, 180.
Covington, Arthur E., An Early 19th-Century Star Map After Aratus, 78; Internal Precision of the Daily Radio Flux Observations at 10.7 Centimetres, 156.
Cygni, SS, 145.

D

David Dunlap Observatory, Notes, 43, 190.
Dome Built by Ancaster Member, 44.
Dominion Astrophysical Observatory, Notes, 95, 240.
Dominion Observatory, Contributions, Vol. 2, No. 29, *Millman*, 15.
Dominion Observatory, Notes, 142, 277.
Douglas, A. Vibert, Astronomers Visit Four U.S.S.R. Observatories, 74.

E

Early 19th-Century Star Map After Aratus, An, *Arthur E. Covington*, 78.
Earth, The Figure of the, *R. K. C. Johns*, 257.
Eclipse Chasing Above the Clouds, *J. E. Kennedy*, 66.
Eclipses, Ten Total, *S. A. Mitchell*, 49.

F

Farquhar, R. M., Geological Time, 34.
Figure of the Earth, The, *R. K. C. Johns*, 257.

G

Geological Time, *R. M. Farquhar*, 34.

H

Halifax Planetarium, The, *M. W. Burke-Gaffney*, 154.
Heard, John F. (see Notes from Observatories and Review of Publications).
Historical Research in Astronomy, *J. E. Kennedy*, 252.
Hogg, David (see Review of Publications).
Hogg, Helen Sawyer, Variable Stars in Star Clusters, 97 (see also Review of Publications).
Hume Cronyn Memorial Observatory, Notes, 191.
Hunten, D. M., Photoelectric Spectroscopy, 204.

I

I.G.Y., Visual Meteor Programme—Progress Report No. 3, 137.
Internal Precision of the Daily Radio Flux Observations at 10.7 Centimetres, *A. E. Covington*, 156.

J

Jacobs, J. A., Magnetic Storms, 85.
Johns, Alfred Edward, Obituary, 233.
Johns, R. K. C., The Figure of the Earth, 257.

K

Kennedy, J. E., Eclipse Chasing Above the Clouds, 66; Historical Research in Astronomy, 252 (see also Notes).
Khan, Abdul Majid, Polaris and Precession (with Charles H. Smiley), 249.
Kingston, H. R. (see Notes).

L

Laboratory Astrophysics, *R. W. Nicholls*, 109.
Laboratory Excitation of Meteoritic Spectra in Shock Tubes, The, *R. W. Nicholls, M. D. Watson* and *W. H. Parkinson*, 223.
Lyrid Meteor Cluster, A, 183.

M

McCallion, William J., The Spitz Planetarium, McMaster University, Hamilton, Ontario (with Truman M. Norton), 149 (see also Notes).
McCarthy, Martin F., S.J., Stellar Populations, 211.
McKellar, Andrew, The President of the R.A.S.C., 179.
MacRae, Donald A. (see Review of Publications).
Magnetic Storms, *J. A. Jacobs*, 85.
Mayall, Margaret W. (see Variable Star Notes).
Meanook-Newbrook Meteor Observatories, The, *Peter M. Millman*, 15.
Meridian Circle, The Ottawa, *E. G. Woolsey*, 264.
Meteor Cluster, A Lyrid, 183.
Meteor Crater Controversy, The Arizona, *Matt Walton*, 162.
Meteor News, 137, 181, 271.
Meteor Procession of February 9, 1913, A Probable Natural Satellite: The, *John A. O'Keefe*, 59.
Meteor Programme—Progress Report No. 3, The I.G.Y. Visual, 137.
Meteor Spectra (Appendix 7), Photographic, 271.
Meteoritic Spectra in Shock Tubes, The Laboratory Excitation of, *R. W. Nicholls, M. D. Watson* and *W. H. Parkinson*, 223.
Meteors, A New General Book on, 181.
Millman, Peter M., The Meanook-Newbrook Meteor Observatories, 15 (see also Meteor News).
Mitchell, S. A., Ten Total Eclipses, 49.

N

New Zealand, Variable Star Observing in (part 2), *Frank M. Bateson*, 1.
Nicholls, R. W., Laboratory Astrophysics, 109; The Laboratory Excitation of Meteoritic Spectra in Shock Tubes (with M. D. Watson and W. H. Parkinson), 223.
Northcott, Ruth J. (see Review of Publications).
Norton, Truman M., The Spitz Planetarium, McMaster University, Hamilton, Ontario (with William J. McCallion), 149.
Notes, 44, 179, 232.
Notes from Observatories, 43, 95, 142, 190, 240, 277.

O

Observatories, Astronomers Visit Four U.S.S.R., *A. Vibert Douglas*, 74.
Observatories, The Meanook-Newbrook Meteor, *Peter M. Millman*, 15.
Observer's Handbook, Error in the 1959, 233.
O'Keefe, John A., A Probable Natural Satellite: The Meteor Procession of February 9, 1913, 59.
Ottawa Meridian Circle, The, *E. G. Woolsey*, 264.

P

Parkinson, W. H., The Laboratory Excitation of Meteoritic Spectra in Shock Tubes (with R. W. Nicholls and M. D. Watson), 223.

Photoelectric Spectroscopy, *D. M. Hunten*, 204.

Photographic Meteor Spectra (Appendix 7), 271.

Planetarium, The Halifax, *M. W. Burke-Gaffney*, 154.

Planetarium, McMaster University, Hamilton, Ontario, The Spitz, *William J. McCallion* and *Truman M. Norton*, 149.

Planetarium, A Sixteenth-Century, *Frederick A. Stebbins*, 197.

Polaris and Precession, *Charles H. Smiley* and *Abdul Majid Khan*, 249.

Populations, Stellar, *Martin F. McCarthy, S.J.*, 211.

Precession, Polaris and, *Charles H. Smiley* and *Abdul Majid Khan*, 249.

Probable Natural Satellite: The Meteor Procession of February 9, 1913, A, *John A. O'Keefe*, 59.

R

Radio Flux Observations at 10.7 Centimetres, Internal Precision of the Daily, *Arthur E. Covington*, 156.

Review of Publications:

Astapowitsch, I. S., Meteoric Phenomena in the Earth's Atmosphere, *Peter M. Millman*, 181.

Bok, Bart J., The Astronomer's Universe, *Helen Sawyer Hogg*, 234.

Callatay, Vincent de, Atlas of the Sky, *Gustav A. Bakos*, 144.

Clason, Clyde B., Exploring the Distant Stars, *Ruth J. Northcott*, 237.

Coleman, James A., Relativity for the Layman, 239.

H.M. Nautical Almanac Office, Planetary Co-ordinates for the Years 1960–1980, referred to the Equinox of 1950.0, 48; Seven-figure Trigonometrical Tables for Every Second of Time, 2nd ed., 239.

Lovell, A. C. B., The Individual and the Universe, *Donald A. MacRae*, 237.

Mayall, Margaret W., Manual for Observing Variable Stars, 48.

Moore, Patrick, Space Exploration, 48.

Naef, Robert A. (editor), Der Sternenhimmel, 48.

Newton, H. W., The Face of the Sun, *David Hogg*, 236.

O'Connell, D. J. K., The Green Flash and Other Low Sun Phenomena, *Leonard Searle*, 47; (editor), Stellar Populations, *Sidney van den Bergh*, 45.

Pickering, James S., 1001 Questions Answered About Astronomy, 48.

Sahade, J., S.-S. Huang, O. Struve and V. Zebergs, The Spectrum of Beta Lyrae, *John F. Heard*, 188.

Smart, W. M., Combination of Observations, *Donald A. MacRae*, 186.

Texereau, Jean, How to Make a Telescope, *Ruth J. Northcott*, 235.

Thiell, Rudolf, And There Was Light, *John F. Heard*, 184.

Underhill, Anne B. and John H. Waddell, Stark Broadening Functions for the Hydrogen Lines, 238.

Vaucouleurs, Gerard de, Discovery of the Universe, *John F. Heard*, 184.

Royal Astronomical Society of Canada, Annual Meeting: Presidential address, 97; Minutes of Meeting, 117; Reports, 118; Officers and Council, 134; Andrew McKellar: President, 179.

S

Satellite: The Meteor Procession of February 9, 1913, A Probable Natural, *John A. O'Keefe*, 59.

Searle, Leonard (see Review of Publications).

Shocks, Shells and Supergiants, *Anne B. Underhill*, 172.

Sixteenth-Century Planetarium, A, *Frederick A. Stebbins*, 197.

Smiley, Charles H., Polaris and Precession (with Abdul Majid Khan), 249.
Smith, Gordon W. (see Notes).
Spectra in Shock Tubes, The Laboratory Excitation of Meteoritic, *R. W. Nicholls, M. D. Watson* and *W. H. Parkinson*, 223.
Spectroscopy, Photoelectric, *D. M. Hunten*, 204.
Spitz Planetarium, McMaster University, Hamilton, Ontario, The, *William J. McCallion* and *Truman M. Norton*, 149.
Star Clusters, Variable Stars in, *Helen Sawyer Hogg*, 97.
Star Map After Aratus, An Early 19th-Century, *Arthur E. Covington*, 78.
Stars, The Characteristics of Subdwarf, *William Buscombe*, 7.
Stebbins, Frederick A., A Sixteenth-Century Planetarium, 197.
Stellar Populations, *Martin F. McCarthy, S.J.*, 211.
Supergiants, Shocks, Shells and, *Anne B. Underhill*, 172.

T

Ten Total Eclipses, S. A. *Mitchell*, 49.
Toronto Meeting of the American Astronomical Society, 245.

U

Underhill, Anne B., Shocks, Shells and Supergiants, 172.

V

Variable Star in Camelopardalis, New, 5h 35.4m + 68° 49′ (1900), 193.
Variable Star Notes, 39, 91, 145, 193, 241, 279.
Variable Star Observing in New Zealand (part 2), *Frank M. Bateson*, 1.
Variable Stars in Star Clusters, *Helen Sawyer Hogg*, 97.

W

Walton, Matt, The Arizona Meteor Crater Controversy, 162.
Watson, M. D., The Laboratory Excitation of Meteoritic Spectra in Shock Tubes (with R. W. Nicholls and W. H. Parkinson), 223.
Wehlau, William (see Notes from Observatories).
Woolsey, E. G., The Ottawa Meridian Circle, 264.

CONTENTS FOR VOLUME 53, 1959

I. FEBRUARY

Variable Star Observing in New Zealand–II ..... *Frank M. Bateson* 1
The Characteristics of Subdwarf Stars ..... *William Buscombe* 7
The Meanook-Newbrook Meteor Observatories ..... *Peter M. Millman* 15
Canadian Scientists Report–XIV (Geological Time: *R. M. Farquhar*) 34
Variable Star Notes ..... *Margaret W. Mayall* 39
Notes from Observatories (David Dunlap Observatory) 43
Notes (Dome Built by Ancaster Member) 44
Review of Publications (*Stellar Populations* edited by D. J. K. O'Connell; *The Green Flash and Other Low Sun Phenomena* by D. J. K. O'Connell; *Manual for Observing Variable Stars* by Margaret W. Mayall; *Planetary Co-ordinates for the Years 1960–1980, referred to the Equinox of 1950.0* prepared by H. M. Nautical Almanac Office; *1001 Questions Answered About Astronomy* by James S. Pickering; *Space Exploration* by Patrick Moore; *Der Sternenhimmel, 1959* edited by Robert A. Naef) 45

II. APRIL

Ten Total Eclipses ..... *S. A. Mitchell* 49
A Probable Natural Satellite: The Meteor Procession of February 9, 1913 *John A. O'Keefe* 59
Eclipse Chasing Above the Clouds ..... *J. E. Kennedy* 66
Astronomers Visit Four U.S.S.R. Observatories ..... *A. Vibert Douglas* 74
An Early 19th-Century Star Map After Aratus ..... *Arthur E. Covington* 78
Canadian Scientists Report–XV (Magnetic Storms: *J. A. Jacobs*) 85
Variable Star Notes ..... *Margaret W. Mayall* 91
Notes from Observatories (Dominion Astrophysical Observatory) 95
Review of Publications (Notice concerning the *Astrophysical Journal*) 96

III. JUNE

Variable Stars in Star Clusters ..... *Helen Sawyer Hogg* 97
Canadian Scientists Report–XVI (Laboratory Astrophysics: *R. W. Nicholls*) 109
Annual Meeting of the Royal Astronomical Society of Canada: Minutes, Reports of the President, National Secretary, Librarian, the Session for Papers, Secretaries of Centres, National Treasurer, Treasurers of Centres, Officers for 1959 117
Meteor News (The I.G.Y. Visual Meteor Programme–Progress Report No. 3) *Peter M. Millman* 137
Notes from Observatories (The Dominion Observatory) 142
Review of Publications (*Atlas of the Sky* by Vincent de Callatay) 144
Variable Star Notes ..... *Margaret W. Mayall* 145

IV. AUGUST

The Spitz Planetarium, McMaster University, Hamilton, Ontario
William J. McCallion and *Truman M. Norton* 149
The Halifax Planetarium ..... *M. W. Burke-Gaffney* 154
Internal Precision of the Daily Radio Flux Observations at 10.7 Centimetres
A. E. Covington 156
The Arizona Meteor Crater Controversy ..... *Matt Walton* 162
Canadian Scientists Report—XVII (Shocks, Shells and Supergiants: *Anne B. Underhill*) 172
Notes (Andrew McKellar: The President of the R.A.S.C.; Obituary: Rev. W. G. Colgrove) 179
Meteor News (A New General Book on Meteors) ..... *Peter M. Millman* 181
Review of Publications (*And There Was Light* by Rudolf Thiell; *Discovery of the Universe* by Gerard de Vaucouleurs; *Combination of Observations* by W. M. Smart; *The Spectrum of Beta Lyrae* by J. Sahade, S.-S. Huang, O. Struve and V. Zebergs) 184
Notes from Observatories (David Dunlap Observatory; Hume Cronyn Memorial Observatory) 190
Variable Star Notes (New Variable Star in Camelopardalis, 5h 35.4m + 68° 49′ (1900) ..... *Margaret W. Mayall* 193

V. OCTOBER

A Sixteenth-Century Planetarium ..... *Frederick A. Stebbins* 197
Photoelectric Spectroscopy ..... *D. M. Hunten* 204
Stellar Populations ..... *Martin F. McCarthy, S.J.* 211
Canadian Scientists Report—XVIII (The Laboratory Excitation of Meteoritic Spectra in Shock Tubes: *R. W. Nicholls, M. D. Watson* and *W. H. Parkinson*) 223
Notes (Chant Medal and Service Award; Obituary: Alfred Edward Johns; Error in the 1959 Observer's Handbook) 232
Review of Publications (*The Astronomer's Universe* by Bart J. Bok; *How to Make a Telescope* by Jean Texereau; *The Face of the Sun* by H. W. Newton; *The Individual and the Universe* by A. C. B. Lovell; *Exploring the Distant Stars* by Clyde B. Clason; *Stark Broadening Functions for the Hydrogen Lines* by Anne B. Underhill and John H. Waddell; *Seven-figure Trigonometrical Tables for Every Second of Time*, H.M. National Almanac Office; *Relativity for the Layman* by James A. Coleman) 234
Notes from Observatories (Dominion Astrophysical Observatory) 240
Variable Star Notes ..... *Margaret W. Mayall* 241

VI. DECEMBER

Toronto Meeting of the American Astronomical Society 245
Polaris and Precession ..... *Charles H. Smiley* and *Abdul Majid Khan* 249
Historical Research in Astronomy ..... *J. E. Kennedy* 252
The Figure of the Earth ..... *R. K. C. Johns* 257
Canadian Scientists Report–XIX (The Ottawa Meridian Circle: *E. G. Woolsey*) 264
Meteor News (Photographic Meteor Spectra–Appendix 7) *Peter M. Millman* 271
Notes from Observatories (Dominion Observatory) 277
Variable Star Notes ..... *Margaret W. Mayall* 279
Index to Volume 53 283
Table of Contents for Volume 53 ..... i to v

Vol. 53, No. 6 **DECEMBER 1959** **Whole No. 441**

Toronto Meeting of the American Astronomical Society 245

Polaris and Precession ..... *Charles H. Smiley* and *Abdul Majid Khan* 249

Historical Research in Astronomy ..... *J. E. Kennedy* 252

The Figure of the Earth ..... *R. K. C. Johns* 257

CANADIAN SCIENTISTS REPORT—XIX
The Ottawa Meridian Circle ..... *E. G. Woolsey* 264

METEOR NEWS ..... *Peter M. Millman* 271

NOTES FROM OBSERVATORIES 277

VARIABLE STAR NOTES ..... *Margaret W. Mayall* 279

INDEX TO VOLUME 53 283

TABLE OF CONTENTS FOR VOLUME 53 ..... i to v

EDITOR—Ruth J. Northcott ASSISTANT EDITOR—Leonard Searle

ASSOCIATE EDITORS—C. S. Beals, R. M. Petrie, A. Thomson

COMMUNICATIONS TO THE EDITORS SHOULD BE ADDRESSED TO

David Dunlap Observatory, Richmond Hill, Ontario

The Society publishes this JOURNAL bi-monthly (February, April, June, August, October and December) and the OBSERVER'S HANDBOOK annually. Single copies of either of these publications are 75 cents.

Membership, which includes the publications, is open to anyone interested in astronomy. Annual dues are $5.00; life membership is $75.00. Application for membership or publications should be made to THE ROYAL ASTRONOMICAL SOCIETY OF CANADA, 252 COLLEGE STREET, TORONTO 2B, ONTARIO.